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THE ILLUMINATION OF RAILWAY YARDS WITH SODIUM LAMPS

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621.327.44 : 628.971.8

Sodium lamps are becoming more and more common for the illumination of railway yards. In addition to the well-known advantages of sodium light such as great contrast, high visibility and speed of observation, slightness of glare, the high efficiency of sodium lamps is also an important factor in the case of railway yards where very large areas must be lighted. In this article different systems of lighting railway yards are dealt with, and several points are indicated which are important in the designing and calculation of the illumination of a railway yard with sodium lamps.

Introduction

An efficient illumination is indispensible for smooth running and safety in shunting operations after dark. The illumination must reveal the shunt lines with the rolling stock on them, buffers, turntables and other items of the equipment of such a yard. It is of particular importance that the position of switches be clearly visible. Although the position of a switch may be deduced from the position of the operating mechanism, or may be indicated by means of a signal, the shunters prefer a direct observation of the position of the switch tongues. Possible doubt about this position will lead to delay and may lead to damage and accidents.

A railway yard has a large surface to be illuminated, and therefore economy prohibits a strong illumination. Moreover, the majority of the objects to be made visible, as well as the ground itself, are dark in colour and without striking colours. In such a difficult situation the emphasis must be laid upon making strong contrasts in brightness, and disturbing factors such as glare must be avoided as much as possible.

The strongest contrasts in brightness between the usually vertical objects and the horizontal ground occur when the light is incident either vertically or approximately horizontally. Two completely different systems of illumination have therefore been developed. This development had already taken place before sufficient theoretical knowledge had been obtained to serve as a guide. Experience had shown what was usable and what could not be considered suitable, which of course does not mean that much of what was usable, and which therefore remained, is not capable of being improved upon.

At the present time gas-discharge lamps and especially sodium lamps are being used to an increasing degree for the illumination of railway yards. Because of this fact experiments have been carried out with this new light source, which is known to be easily capable of providing the required strong contrasts. Moreover, the high efficiency of the sodium lamp is a factor which may not be too lightly estimated, because of the large area to be lighted. In the following we shall discuss the ordinary systems for the illumination of railway yards and then investigate the advantages to be obtained by the use of gas-discharge lamps.

Two systems of illumination of railway yards

The first and oldest lighting system consists of a number of standards with lanterns distributed more or less uniformly over the yard. Initially these lanterns had no definite light distribution which made them particularly efficient for the purpose in view. They gave light, and that was, in those times, almost the only requirement made of illuminating engineering. Since an increase in intensity of the light sources used accompanied the development of the railway industry, measures had to be taken to decrease the disturbing glare. Diffusing bulbs were at first used to decrease the brightness of the source of light. This measure is, however, of only moderate help in dark surroundings, so that enam-

melled reflectors began to be more commonly used. These restricted the radiation to a cone with an apex angle of 2 × 70° to 2 × 75°. By this restriction of the radiation not only was the glare reduced to a negligible quantity [1]), but in addition the intensity of illumination was about doubled in comparison with the older freely radiating fixtures which waste a large amount of light by radiation upward and to the sides.

The second system of lighting is also old, and it arose when electric filament lamps of high power became available. These lamps are mounted in mirror reflectors which give concentrated beams of great intensity. These searchlights are set up in batteries at some height, and the beams are directed on to the yard about in the main direction of the tracks (*fig. 1*).

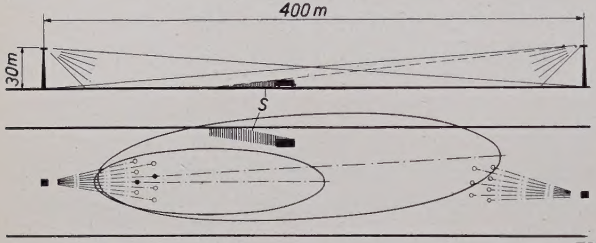

Fig. 1. Schematic illustration of illumination by means of search lights. Each part of the yard must be lighted from two sides, in order to prevent the formation of long shadows (S) as much as possible. Eight projectors are mounted on each standard The small circles indicate the spots where the axes of the light beams touch the ground. The ellipses indicate the parts of the yard lighted by the beams of 30° for the two black circles. The beams do not have sharp boundaries and light also falls outside the ellipses.

Both systems have their advantages and disadvantages. For the first system a cable network is necessary, which covers the whole yard. The installation of this net is fairly expensive because of the many unavoidable crossings of the tracks. The second system has the advantage of a very simple supply network, since the current consumption is concentrated at only a few points. Over against this is the disadvantage that the high positions for mounting are usually absent and must be built in the form of standards 15 to 35 m in height.

From the point of view of light technology the use of scattered lanterns is in general to be preferred to the use of searchlights, as will be seen in the following discussion of the most important characteristics of the two systems.

Efficiency

The efficiency of a simple enamelled fixture is 55 to 65 per cent, *i.e.* 55 to 65 per cent of the light flux is directed downward toward the ground. Some light is obviously lost because it falls outside the boundary of the yard, but this quantity is not large when the system is properly installed.

With a good mirror reflector the beam with an apex angle of 2 × 15° includes 30 per cent of the total light flux of the lamp, thus much less than with scattered lanterns. The stray light, which represents about 35 per cent of the light flux of the lamp, is practically lost (*fig. 2*).

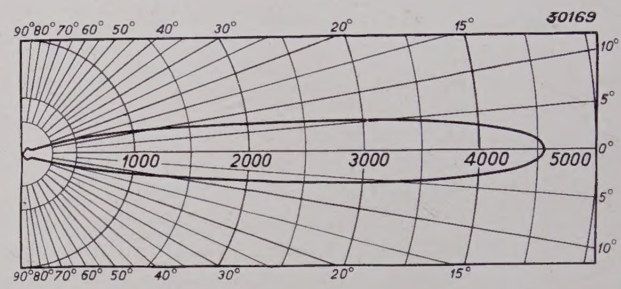

Fig. 2. Light distribution of the projector FLC 1.

Loss of light due to dirt and mist

In both systems dirt on the fixtures will cause a weakening of the illumination. In the case of the simple enamelled reflectors dirtiness results in a decrease of the reflective power, and the light distribution changes only slightly. With mirror reflectors there is not only absorption in the covering glass and a decrease in the reflective power of the mirror, but in addition a scattering of the beam. The influence of dirt is therefore larger than with scattered lanterns. The loss of light due to mist is also greater in the case of concentrated light beams than with the scattered arrangement, because the rays have to cover longer distances through the air.

Formation of contrast

In judging the contrast two things must be distinguished, the brightnesses of the rather diffusely reflecting surfaces of the carriages, the side surface of the rails and the ground, and the brightness of the smooth, specular running surfaces of the rails.

With the system with scattered lanterns the light falls mainly from above. In general therefore the vertical walls of the carriages will be less strongly lighted than the ground, in the same way the vertical surfaces of the rails will remain dark. The shadows will be short, and will therefore not only cause little trouble, but will also serve to bring out the line of the rails.

On the running surface of the rails a moderate reflection takes place at the point where the rails lie between the observer and a lantern. The tracks are

[1]) See the article: Technical considerations in the lighting of country roads, Philips techn. Rev. 2, 239, 1937.

therefore seen as bright bands against a dark background (see *fig. 3*). Since when a long shunting yard is seen in perspective the lanterns are seen scattered over the whole width, this reflection will occur throughout the whole yard except where the carriages intercept the light rays, *i.e.* in the shadows. The state of illumination has the same character as that in daylight as regards average brightnesses.

of incidence. The contrast obtained is thus confined to the surfaces which stand more or less perpendicular to the length of the yard.

Glare

In the case of illumination with search lights glare forms a serious obstacle. It is impossible to give the beams such a steep slope that no radiation strikes the eye within an angle of 15° with the direction of vision. If this were done the sphere of action would be so reduced (see fig. 4) that the system would no longer meet the requirements. Moreover, the scattered light which is emitted outside the effective beam would also be able to cause glare. By locating the lights at one side the glare can be

Fig. 3. The photograph shows how the bright running surface of the rails contrasts with the dark sides and the ground. The position of the switch tongues is clearly visible. The carriages are easily seen by the contrast in brightness with their surroundings. Within the short shadow of the carriage in the middle of the photograph the reflection of the rails disappears.

With illumination by means of concentrated beams the intensity of illumination on the sides of carriages toward the light source is stronger than the illumination on the ground. Since the chief directions of vision correspond approximately with the direction of the illuminating beams (because of the greater lengthwise dimension of the yard) the objects will appear bright against the dark background of sky and ground. If there are also beams which radiate in the opposite direction the reflection by the rails is very strong. This a favourable condition, but the long shadows are apt to spoil the efficiency.

Illumination of the side walls of the cars is impossible unless the batteries of lights are stationed along one side of the yard (see *fig. 4*). Even then it is impossible to obtain a strong illumination of the side walls because of the unfavourable direction

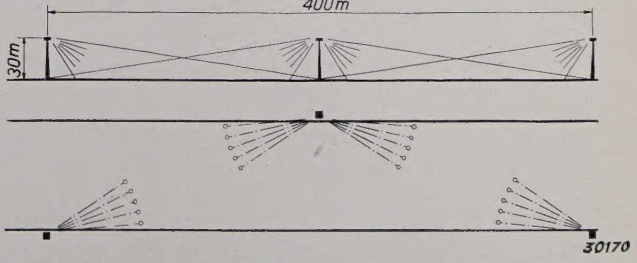

Fig. 4. In order to reduce the glare the beams may be directed obliquely to the general direction of observation and downward as much as possible. This, however, reduces the sphere of action of the batteries and makes a larger number of standards necessary.

reduced for the main direction of the yard. The objection to this is, however, that lights would have to be set up at more points, which would increase the cost of installation.

From the foregoing it may be seen that better results are in general to be expected from an illumination of railway yards with scattered lanterns, if well carried out, than from an illumination with searchlights. In order to understand how the use of searchlights was ever able to maintain itself, it must be kept in mind that this type of illumination originated at the time when illumination with scattered light sources also produced considerable glare because of the use of freely radiating lanterns.

Application of gas-discharge lamps in railway yards

If we now investigate whether certain gas-discharge lamps, especially sodium and mercury vapour lamps, offer special advantages for the illumination of railway yards, the following factors must be considered:

a) The gas-discharge lamp has a high efficiency, with which not only a saving of current, but also an increase of the level of illumination can be attained. Among the various gas-discharge lamps, the sodium lamp is more efficient than the mercury lamp.

b) The incorrect colour reproduction by gas-discharge lamps is of little or no importance in shunting operations.

c) With mercury lighting as well as with sodium lighting a high visibility is attained [2]).

d) The speed of observation is higher with sodium light than with ordinary electric light or mercury light [2]).

e) The contrast is considerably greater with sodium light of low intensity than with ordinary electric light or mercury light of the same intensity [3]).

f) The disturbing effect experienced by looking directly into the light source (afterimages) or by the influence of reflection in puddles (direct and indirect simultaneous glare) is at a minimum with sodium light.

On the basis of these considerations various countries have begun to use "Philora" gas-discharge lamps for the illumination of railway yards. The sodium lamp is usually chosen because, as appears from the above, it satisfies the purpose better than the mercury lamp. Of the two systems of illumination described above only the first one may be considered because the sodium lamp is too large a source of light to be used in projectors.

At the beginning of 1934 the Netherlands Railways carried out an experiment in the railway yard at Amersfoort. This was followed by a permanent installation in the Born yards in South Limburg. The results were so good that new railway yards will always be provided with sodium illumination, and in older installations the electric filament lamps are being gradually replaced by sodium lamps (Philora SO 85 W).

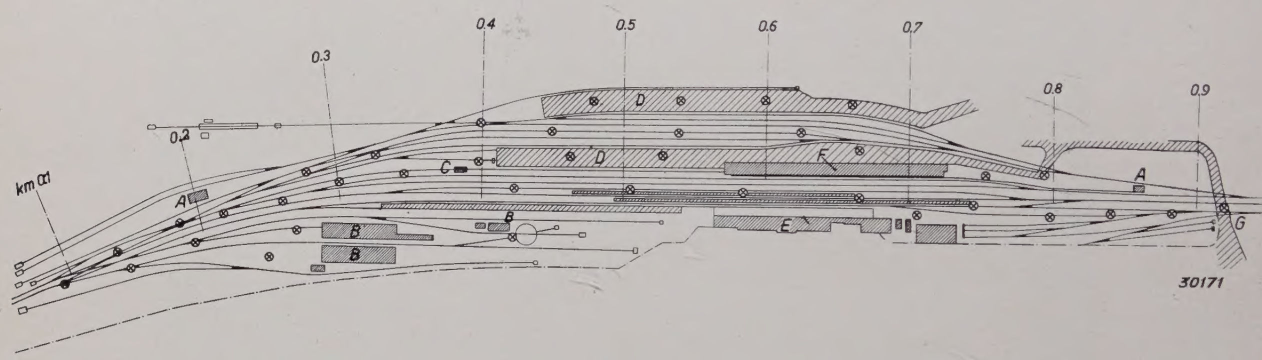

Fig. 5. Ground plan of the railway yard in Breda. *A* signal box, *B* work shops, *C* weighing cabin, *D* unloading yard, *E* station building, *F* goods shed, *G* level crossing.

The experience which has been obtained in practice [4]) confirms the presence of the above-mentioned advantages of sodium light for lighting railway yards. Moreover, another advantage was found in the fact that considerable saving was achieved in the installation of the cable network as may be seen in the following paragraph.

Because of the small amount of power taken from the mains the voltage loss is relatively low. Moreover, the sodium lamp is less sensitive to changes in

[2]) See P. J. Bouma: Visual acuity and speed of vision in road lighting, Philips techn. Rev. **1**, 215, 1936.

[3]) P. J. Bouma: Contrast with sodium light, mercury light and white light, De Ingenieur **49** A, 290, 1934. See also Philips techn. Rev. **1**, 166, 1936.

[4]) See in this connection G. J. de Vos van Nederveen Cappel, Sodium lighting on railway yards, Ingenieur **52** V, 41, 1937.

voltage than an electric filament lamp, *i.e.* the decrease of the light flux is very much less for a given fall in voltage. In addition the lamp transformers for "Philora" sodium lamps are provided with taps which make it possible to neutralize a certain voltage loss.

In the installation of new systems it is possible to use conductors with a smaller cross section if sodium lamps are used, and this means a not inconsiderable reduction of the capital invested.

Technical features of the illumination of railway yards with sodium lamps

The following must be kept in view in the installation of a sodium lamp system:

The intensity of illumination on the ground must be on the average not lower than 1 lux. If we take into account a decrease of the level of illumination by 50 per cent due to the lamps and reflectors becoming dirty, a decrease which must certainly be expected in a railway yard, then a new installation must be calculated on a basis of an average intensity of 2 lux.

If one counts on an efficiency of 60 per cent of the reflectors, and a loss of light which falls outside the yard of 20 per cent, then the light flux per square metre of the lamps to be installed is

$$f = \frac{2}{0.6 \times 0.8} = \text{about 4 lumens.}$$

This means for sodium lamps with an efficiency of about 60 lm/W, a power of 0.07 watt per square metre of surface. According to this one may for example install one "Philora" sodium lamp SO 85 W (light flux 6 500 lumens) per 1600 sq.m. of surface.

In practice account must be taken of the fact that certain parts of the grounds must be better lighted than the rest, for instance at the points

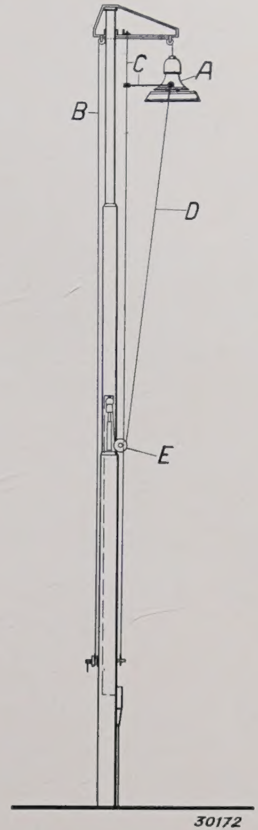

Fig. 6. Method of mounting the fixture for sodium illumination. The cast-iron cap A hangs by the steel wire B which can be run out. Two more steel wires C help to prevent swinging of the fixture in the wind. For the same reason the cast-iron cap is heavily constructed and also contains the leakage transformer of the sodium lamp. The flexible supply lines D are kept taught with the help of two rollers E.

Fig. 7. Railway yard, Dijksgracht, Amsterdam, lighted with 39 "Philora" sodium lamps SO 85 W. The height of the light points is 10.5 m.

where there are many switches, or where different parts of trains are customarily ranged alongside of each other. At such places it is usually necessary to place the lanterns closer together, not primarily to obtain a stronger illumination, but mainly to neutralize the shadows occurring in the compass of one lantern by the light of another lantern. Therefore the power installed will be increased at such a spot to 0.1 to 0.15 watt per sq.m.

On the ground plan of the railway yard in Breda (*fig. 5*) it may be seen that the ends of the yard, where relatively many switches are located, are more thickly occupied by lanterns than the middle section with straight continuous tracks.

The light distribution of the reflectors for sodium lamps is not symmetrical in all directions. The maximum light intensities lie in the plane perpendicular to the axis of the lamp. The reflectors must therefore in general be mounted perpendicular to the length of the yard.

In a railway yard, as already suggested, the lanterns will quickly become dirty because of the large quantities of smoke and soot in the air. Regular cleaning is therefore essential. To facilitate this the fixtures are best mounted in such a way that they can easily be lowered. In *fig. 6* the method of hanging the lanterns used by the Netherlands Railways is shown, while in the text under the figure further particulars are given. Finally *fig. 7* is a photograph of a railway yard in Amsterdam which is lighted with sodium lamps in the fixtures shown in fig. 6.

A PHOTOMETER FOR THE INVESTIGATION OF THE COLOUR RENDERING REPRODUCTION OF VARIOUS LIGHT SOURCES

by P. M. VAN ALPHEN. 535.247.4 : 535.62 : 628.93

For the investigation of the colour reproduction obtained with different kinds of light a photometer has been developed in this laboratory with which it is possible to measure the light flux in definite wave-length regions of the spectrum. The photometer is described in this article. Special attention is paid to the circuit which is used for the measurement of very small photocurrents. Finally it is shown by means of several examples what type of investigations can be carried out with this instrument.

The colour reproduction of various sources of more or less white light has been repeatedly discussed in this periodical. It was always pointed out that it is impossible to conclude from the colour of the light radiated, how the colours of illuminated objects will be reproduced under the light in question. In order to judge this one must know how the intensity of the source of light varies as a function of the wavelength. A complete description of a light source therefore must include a curve or an elaborate table.

It is of course desirable to be able to characterize a light source by means of a smaller number of values, and it was actually found possible to divide the spectrum into eight different blocks in such a way, that the colour reproduction of a kind of light is sufficiently accurately characterized by the value of the light flux which is emitted in each of these eight blocks. This block method is often applied in this laboratory in the investigation of light sources and has often been mentioned in this periodical [1]).

The following will be a description of the photometer which was designed especially for these measurements. Several examples will then be discussed which serve to give an impression of the usefulness of the instrument.

The choice of the blocks

The blocks must be chosen so small that the colour of commonly used pigments does not change significantly under the light when shifted within one block. In order to attain this requirement to the same degree for every colour it was found necessary to choose the intervals smaller in the blue than elsewhere. The following division proved satisfactory: 4 000—4 200—4 400—4 600—5 000—5 500—6 000—6 500—7 000 Å.

Later, in connection with the photometry of mercury light, a somewhat different division was

[1]) See for example the articles: P. J. Bouma, Colour reproduction in the use of different sources of "white light", Philips techn. Rev. 2, 1, 1937: W. Uyterhoeven and G. Zecher, Low-pressure mercury discharge within a luminescent tube, Philips techn. Rev. 3, 277, 1938; G. Heller, A film projection installation with water-cooled mercury lamps, Philips techn. Rev. 4, 2, 1939.

adopted, namely: 4 000 - 4 200 - 4 400 - 4 600 - 5 100 - 5 600 - 6 100 - 6 600 - 7·200 Å.

In the first-mentioned division the green mercury line of 5 461 Å would have fallen practically on the boundary between two blocks, which is undesirable practically because a small error in the adjustment of the blocks would lead to the light flux of that line being divided between two blocks in quite different ways. As to the value of the blocks for colour impression, the new division is practically equivalent to the one first chosen.

The principle of the measuring process

The principle of the measuring process is illustrated in *fig. 1*. Light from the source being investigated falls on a slit S of a prism spectroscope. By means of lens L and prism P a spectrum is thrown on the window D. In this window there is an opening at the point where the block of light being measured is incident. The radiation transmitted is measured by means of a photocell F. The height of the opening in the window D has been made to correspond to the sensitivity of the eye for that wave length for every wave length of the spectrum, and in such a way that the photocurrent, which with a given intensity also depends upon the wave length, is a direct measure of the light flux which is emitted in the block of the spectrum under consideration. By using different screens with openings at different parts of the spectrum corresponding with the different blocks, the light flux can be measured in the eight blocks of the spectrum.

Although the principle is very simple, the technical execution presents difficulties which we shall here discuss briefly. The light flux available, as will be shown later, is extremely small, so that for accurate measurement it is necessary to exclude absolutely any influence from scattered light, especially from scattered light with undesired wave lengths. For this purpose it is desirable to use a double monochromator, by which the already small light flux is reduced even more. A description of the measuring arrangement will preceed the estimation of the light flux.

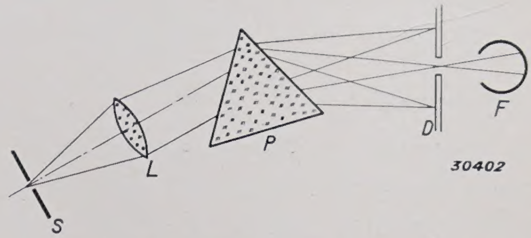

Fig. 1. Diagram of a spectrometer for the determination of the light flux in a certain section of the spectrum. A spectrum of the light which passes through the slit S is formed by means of the lens L and the prism P on the window D. This window has an opening which transmits only a certain part of the spectrum. The light flux transmitted is measured by means of the photocell F.

The measuring arrangement

Fig. 2 is a diagram of the complete measuring arrangement. In an Ulbricht sphere A, 50 cm in diameter, the lamp to be tested is placed. The walls of the sphere illuminate the slit S_1 which is 0.3 mm wide. By means of the achromatic lenses L_1 and L_2 and the prism P a spectrum is formed on the plane DD'. In this plane there is a diaphragm which transmits a certain block of the spectrum. The function of this plane is to cut off scattered light. The plane DD' is situated between two lenses V_1 and V_2 which form an image of lens L_2 on lens L_3, so that every ray of light which leaves lens L_2 also passes through lens L_3.

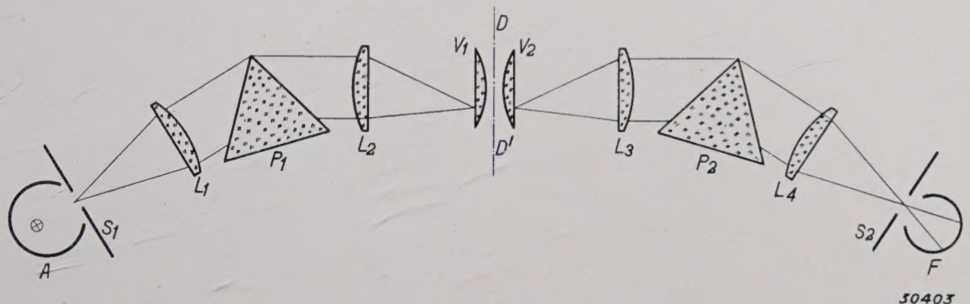

Fig. 2. Arrangement of a spectrometer on the same principle as in fig. 1. In order to avoid scattered light the set up of fig. 1 is elaborated to a double monochromator. The light source is placed in an Ulbricht sphere A.

The paths of the rays for all non-scattered rays on both sides of DD' are mirror images of each other. It follows from this that the rays of different wavelengths which pass through a slit in the screen S_1 are again focussed on a slit in the screen S_2 and finally reach the photocell F. If, however, due to reflection or scattering, light of a given wave length passes through the wrong block opening in DD' then this light is so refracted by prism P_2 that it

does not strike the slit and cannot therefore act on the photocell.

Because of the arrangement described the photocell receives light only from a certain block of the spectrum. We shall now discuss the photocurrents which may be expected as a result of this illumination.

The available light flux in a block

The total light flux which passes through the apparatus is the following:

$$\Phi = K \cdot \pi \cdot B \cdot O \cdot \sin^2 {}^1\!/_2\, \varphi \text{ lumen} \quad (1)$$

where φ is the angle of divergence of the monochromator, O the area of the first slit, B the brightness of the first slit, and K the loss factor.

The light strength of the spectrograph is determined by the relative aperture of the lens L_1. In our case this is 1 : 3·5 (*i.e.* ${}^1\!/_2\, \varphi = 8°$), which may be considered a high value. The image of the slit is focussed on the plane DD' in actual size, and a spectrum is formed in that plane whose total width is about 15 mm, so that each block is 1.5 to 2 mm long. If the wave length regions are to be fairly accurately defined, the width of the first slit must be sufficiently small compared with this 1.5 mm. The height of the slit is limited by the appearance of aberration for object points ouside the axis. We chose a width of 0.3 mm and a height of 17 mm, so that the area O was equal to 0.051 sq.cm.

In order to be able to measure the light flux of small lamps with an Ulbricht sphere it is desirable to be able to work with a low brightness in the plane of the slit, for example $B = 0.1$ c.p./sq.cm.

The loss factor K is quite considerable because the light must pass through nine glass bodies (six lenses, two prismas, and the window DD', since the diaphragm in this plane is deposited on glass photographically). The loss in the glass is caused chiefly by reflection. The average transmission of each glass body is about 90 per cent, so that the total transmission will be:

$$K = 0.9^9 = 40 \text{ per cent.}$$

For the light flux Φ according to equation (1) we find:

$$\Phi = 0.4\, \pi \times 0.1 \times 0.051 \times \sin^2 8° = 125 \times 10^{-4} \text{ lumen.}$$

Only a small part of this light flux is found in the blue block from 4 000 - 4 200 Å. In the case of sunlight this part is about 0.01 per cent; in the case of many sources of artificial light, which usually contain less blue, the amount of blue radiation will be ten times as small.

If it is desired to measure this amount of blue radiation of 0.001 per cent with an accuracy of 5 per cent, it is necessary to be able to distinguish differences in light flux of 0.6×10^{-10} lumen. A vacuum photocell was chosen with potassium as the photo-sensitive material. These cells are very constant and have a sensitivity of 40 μ A/lumen in the light of an ordinary electric lamp. In the first blue block the sensitivity is about 100 times greater than this. When this cell is used and light differences of 10^{-10} lumen must be registred it must be possible to measure a current difference of about 10^{-13} A.

How such small photocurrents are measured

The very small photocurrent can easily be measured by changing the charge on a condenser by means of this current, and measuring the difference in voltage between the plates of the condenser electrostatically. This can for instance be done by means of a so-called electrometer triode, *i.e.* a triode whose control grid is very carefully insulated from the other electrodes.

In *fig. 3* the circuit is given which was used for measuring the photocurrent. The photocurrent flows from the photocell F to the covering *1* of the condenser C. The grid of the electrometer triode T (type 4060) is connected to the same covering.

When the voltage of this grid changes, the anode current, which can be read off on the micro-ammeter B, also changes.

The other plate of the condenser is connected with a potentiometer. By moving the contact of the potentiometer toward the right the grid voltage of the triode, which is about 1 volt negative at the beginning of the measurement, can be made more negative. In this way, the increase of the grid

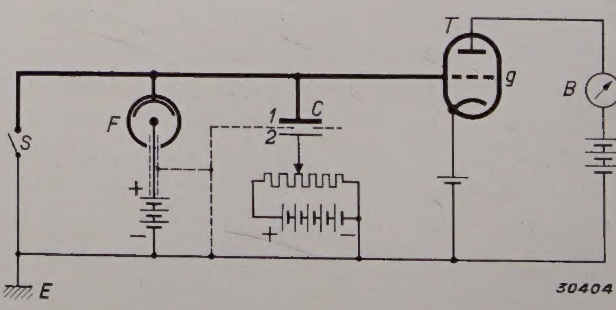

Fig. 3. Circuit for the measurement of the photocurrent. The photocurrent from the cell F changes the charge on the condenser C and consequently also the voltage on the grid g of the electrometer triode T. This voltage is kept constant while the photocurrent flows by moving the potentiometer so that the anode current (instrument B) remains constant. The time t in which the voltage on the potentiometer changes by a certain value V is a measure of the photocurrent i, since $i = CV/t$.

voltage which is due to the photocurrent can be continually compensated and the anode current remains constant.

The measurement is begun by opening the switch S. The grid thus has the potential of the earth terminal E at the beginning of the measurement, and is kept at this potential during the measurement by sliding the potentiometer contact. The time is measured in which the voltage on the potentiometer is changed by a certain value V. If C is the capacity of the condenser and t the time measured, the photocurrent is

$$i = C\,V/t.$$

If we choose the voltage to be compensated $V = 1$ volt, and if the capacity $C = 100$ μμF, then with a current of 10^{-12} A the charging time is 100 sec. Since this charging time is easily measured reproducibly with an accuracy of 1 sec, the accuracy of measurement is 10^{-14} A, which is quite sufficient. If the capacity C is made smaller the sensitivity becomes even greater. The limit is given by the irregularity of the ever present grid current and lies at about 10^{-17} A.

In order to attain this great accuracy various precautionary measures must be taken. In the first place the apparatus must be shielded from external disturbances by placing the whole thing in an earthed container. Care must also be taken that the voltage of the battery of the photocell remains quite constant, since variations in this voltage can act on the system *via* the capacity of the photocell. Finally care must be taken that no leakage currents are able to flow from the part of the circuit drawn with heavy lines.

One advantage of the arrangement is that this last requirement can be easily satisfied. The portion of the circuit which is sensitive to leakage currents remains at earth potential during the entire measurement so that leakage can be avoided by placing screening plates at dangerous points and connecting them with the earth terminal E. Moreover the air in the metal container in which the apparatus is situated is carefully dried with phosphorus pentoxide. Only three parts then require a very high insulation: the cathode of the photocell with respect to the anode, the plate of the condenser with respect to the other plate, and the grid of the electrometer triode with respect to the anode. In the photocell and the triode the insulating medium is a high vacuum; it was found desirable to place the condenser also in a vacuum in order to avoid leakage current due to the presence of ionized air between the plates when this was not done.

The calibration of the photometer

The apparatus was calibrated by placing a tungsten band lamp with known spectral distribution in front of the slit S_1, and then moving a narrow slit slowly across the spectrum DD'. In this way the strength of the photocurrent was measured for every wave length. The curve resulting does not agree with the spectral distribution curve of the lamp because the sensitivity of the photocell varies in quite a different way with the wave length (it changes much more slowly with the wave length) from the sensitivity of the eye which we assume to be given by the international eye-sensitivity curve.

If we wish the photocurrent to be a direct measure of the light flux, the height of the opening in the screen DD' can be so chosen for every wave length that with equal intensity of radiation the photocurrent of the radiation transmitted is proportional for every wave length to the eye sensitivity for the wave length in question.

The proportionality factor need not be constant for the whole spectrum, but can be chosen separately for each of the eight blocks. This has the advantage that in the blue blocks, although the eye sensitivity is very low here, we nevertheless can obtain fairly large photocurrents in order to measure the small quantities of light in the blue with sufficient accuracy. In the calculation of the photocurrent this is taken into account by assuming that the sensitivity of the photocell in the blue block is 100 times as great as for ordinary electric light where the greater part of the light flux lies in blocks 5 and 6.

Making the blocks

The shape of the blocks which is determined by the above described calibration is shown in *fig. 4.* In the middle of the spectral region (blocks 5 and 6), where the sensitivity of the cell shows almost the same variation as the sensitivity of the eye, the height of the blocks is practically

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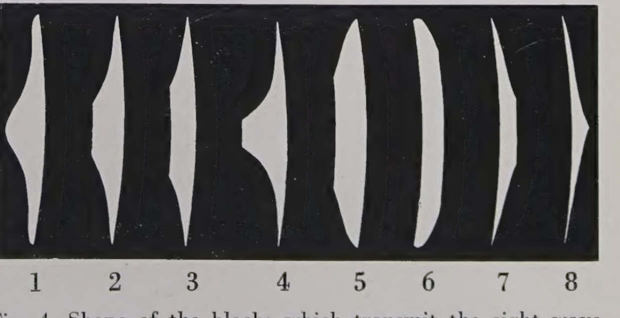

Fig. 4. Shape of the blocks which transmit the eight wave length divisions of the spectrum.

constant, but in the red and blue sections the top and bottom are cut away, because in these blocks the eye sensitivity decreases more strongly than the sensitivity of the cell with increasing or decreasing wave length. The wave length boundaries of the blocks are curved because the spectral lines are also curved in the spectrograph.

A tenfold enlarged drawing is made of the calculated shape of the blocks. This is photographed in a tenfold reduction on a plate and from the negative so obtained a positive copy is made on a second plate. In the choice of the kind of plate and the developer, fine grain and great hardness was sought. In this way the transparent region of the block was absolutely clear: no grains could be observed under the microscope. These prints were mounted in metal slides and are used immediately as diaphragms for the corresponding blocks.

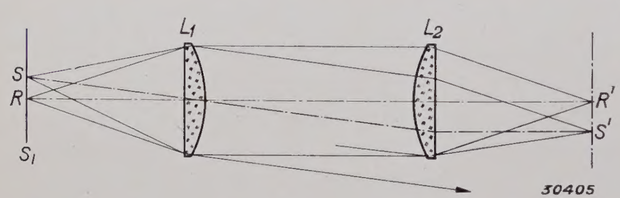

Fig. 5. Formation of the image of the first slit S_1 on the screen DD' (see fig. 2). The middle R of the slit is focussed on the screen with a greater intensity than the upper or lower end (S) because a vignette effect occurs in the focussing of the ends of the beam.

In order to be able to adjust the blocks accurately in relation to the spectrum, a small dot was made on each block at the point where, when correctly placed, a known spectral line should fall (a line of mercury or helium for example). The adjustment could now be checked by examining the block and the spectrum projected upon it with a magnifying glass. By means of a setting screw the block was given the correct position.

In calculating the shape of the blocks the following must be kept in mind. If it is necessary to reduce the light flux by a factor $^1/_2$ for a certain wave length, it is not enough to decrease the height of the slit by one half. Even though the illumination of the first slit is absolutely uniform over its entire height, this is not the case for the highest part of the spectrum. This is due to the vignette effect of the lenses L_1 and L_2 (see *fig. 5*). Since there is a prism between these lenses, the lenses are about 8 cm apart. The whole of the cone of light which passes from the middle R of the slit S_1 through lens L_1 also passes through L_2, but the beam which passes through L_1 from the point near the end S is only partially incident on L_2. The result is that the upper and lower edge of the spectrum are more weakly illuminated than the middle. This variation in illumination is determined experimentally (see *fig. 6*) and taken into account in fixing the shape of the blocks.

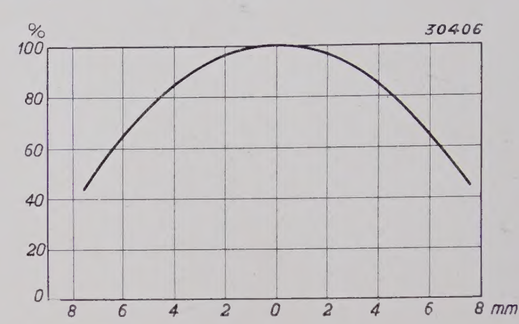

Fig. 6. Variation of the intensity as a function of the height of a spectral line when the first slit is uniformly illuminated.

Checking the photometer

It is possible to check the position of the blocks by examining the light leaving the last slit by means of a spectroscope. In *fig. 7* the spectra are reproduced which were obtained by photographing the spectrum of the electric lamp in the eight blocks. The eight transmitting regions are seen to succeed each other continuously from 4 200 to 7 200 Å.

The results obtained with the photometer were checked by investigating three standardized light sources whose spectral distributions are known. These sources of light are obtained with an electric lamp of 2840° colour temperature with different liquid filters. Light sources are obtained in this way which correspond as to colour: A with an ordinary gas-filled tungsten filament lamp, B with sunlight (colour temperature 4 800°) and C with average daylight (colour temperature 6 500°).

The light flux of these sources was measured

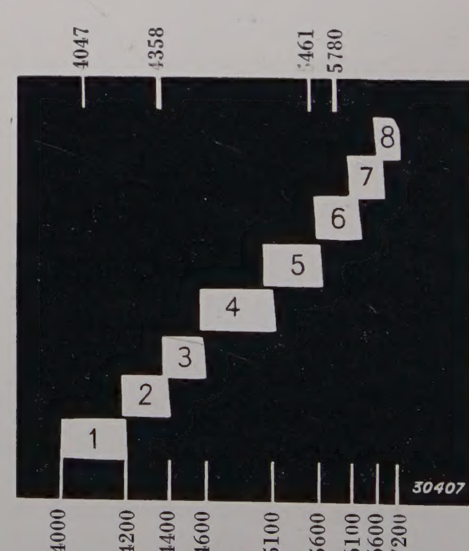

Fig. 7. Spectrum of the light which is transmitted through the eight blocks of the spectrometer.

Table I.

Relative light flux (% of the total light flux) radiated by different standard light sources in the different blocks of the spectrum.

Wave length limits of the blocks in Å		4000 – 4 200	4 200 – 4 400	4 400 – 4 600	4 600 – 5 100	5 100 – 5 600	5 600 – 6 100	6 100 – 6 600	6 600 – 7 200
Strong mercury lines in blocks		4047	4358			5461	5780		
Number of block		1	2	3	4	5	6	7	8
Colour		violet	blue		blue/green	green	yellow/orange	red	
Standard A	calculated	0.005	0.06	0.25	5.4	33.5	42.7	16.6	1.54
	measured	0.006	0.06	0.25	5.1	34.3	42.8	16.1	1.42
Standard B	calculated	0.016	0.18	0.64	9.2	39.3	38.2	11.6	0.91
	measured	0.018	0.19	0.72	9.3	40.5	37.4	11.0	0.86
Standard C	calculated	0.025	0.26	0.91	11.1	40.8	36.2	9.9	0.73
	measured	0.029	0.29	1.04	11.4	42.1	35.4	9.2	0.70

in the eight blocks and also calculated from the known spectral distribution. The measured and calculated values are given in *table I*, and show satisfactory agreement.

Special care is necessary in the photometry of line spectra. If a line falls at a point in a block where the height of the transmitted part of the spectral line changes rapidly with the wave length, a slight inaccuracy in the position of the diaphragm may exert a great influence. Therefore the adaptation of the photometer to the international eye-sensitivity curve was specially checked for the spectral lines of most practical importance, namely those of the mercury lamp. This was possible by determining the spectral distribution of energy of a mercury lamp by means of a thermopile.

Several examples of applications

The most important application is for the estimation of the colour reproduction of sources of white light. We may refer the reader to the articles mentioned in the first footnote for this subject. In *table II* are given the results of measurements on several lamps and natural sources of light.

The first lines of the table show how electric light differs from sunlight by an excess of red and too little blue, and how this difference can be compensated to a large degree by the use of a suitable filter (sunlight lamp). From the other items it may be seen that the mercury lamp deviates very much from daylight by an excess of violet and a lack of red; this deviation is much greater with the low-pressure mercury tube than with the high-pressure mercury tube (HP 300). The last lines show how it is possible by the use of fluorescent substances with a discharge in mercury vapour to obtain a source of light which, as to spectral composition, is intermediate between electric light and daylight.

A quite different type of application is the numerical determination of the tint of coloured objects under a given illumination. When a surface, whose reflective capacity as a function of the wave length is known, is irradiated with light of known spectral composition, the colour of the surface can be given by calculating the corresponding coordinates in the colour triangle. Another determination which is more obvious is obtained by calculating the dominating wave length and the saturation [2]).

When the reflective capacity of the surface may be considered constant within a block, it is sufficient to indicate the reflection in the eight blocks instead of the whole spectral variation of the reflection. If in addition the light flux of the source in the eight blocks is known, an appreciable saving of work in measurement and calculation is obtained in this way.

As an example we give in *table III* the dominating wave length calculated in this way and the saturation for the colour of the human skin and for the colour of oak when illuminated with different sources of light. It may be seen that the skin, which has a yellowish colour in daylight (wave length 5 860 Å), does not change much under electric light (5 890 Å), but takes on a deeper colour. Under the mercury lamp the colour is a little saturated greenish-white. By the application

[2]) For the calculation of colour coordinates, dominating wave length and saturation see: P. J. Bouma. Philips techn. Rev. **1**, 283, 1936; **2**, 39, 1937.

Tabel II.

Relative light flux radiated by different sources of light, natural and artificial in the different blocks of the spectrum.

Limits of blocks in Å	4 000–4 200	4 200–4 400	4 400–4 600	4 600–5 100	5 100–5 600	5 600–6 100	6 100–6 600	6 600–7 200
Number of block	1	2	3	4	5	6	7	8
"Bi-Arlita" tungsten lamp	0.005	0.05	0.23	5.3	32.7	42.2	17.7	1.8
Sunlight tungsten lamp	0.009	0.09	0.40	7.6	38.6	39.5	11.7	1.0
Sunlight	0.016	0.18	0.64	9.2	39.2	38.2	11.6	0.9
Average daylight	0.025	0.26	0.91	11.1	40.8	36.2	10.0	0.7
HP 300 (mercury lamp)	0.017	0.83	0.09	0.92	51.5	45.8	0.7	0.06
HPL 300 (with fluorescence)	0.007	0.23	0.15	1.57	46.4	47.3	4.1	0.29
Low-pressure mercury tube	0.05	3.1	—	1.0	75.5	20.3	—	—
Idem with fluorescence	0.003	0.27	0.03	1.0_1	33.7	48.7	15.8	0.58
Idem different type	0.006	0.33	0.20	4.2	38.5	43.1	13.4	0.61

Table III.

Colour of the skin and of oak when illuminated with different kinds of light.

Light source	Skin colour (palm of hand)		Oak (stained)	
	Wave length (Å)	Saturation (%)	Wave length (Å)	Saturation (%)
Electric lamp	5 890	70	5 870	72
Daylight	5 860	22	5 860	26
Mercury lamp with fluorescence	5 710	70	5 710	70
Mercury lamp	5 500	24	5 500	20

of fluorescent bulbs the dominating wave length is shifted toward the red, and in addition the saturation increases from 24 to 72 per cent.

The colour of oak corresponds quite well with that of the human skin. This is also observed directly when both are so strongly illuminated that they have the same brightness.

It is clear that in this way the colour reproduction can be calculated with simultaneous illumination with different sources, thus with mixed light. This may be important in cases where the reproduction of a certain colour, for instance that of the human face or of furniture, is of special importance for the value of the illumination.

A MOTOR VAN FOR SOUND RECORDING BY THE PHILIPS-MILLER SYSTEM [1])

681.84.081

A motor van is described which is equipped for sound recording by the Philips-Miller system previously described in this periodical [1]). The advantages are discussed of this system over sound recording systems in use until now, in general, and particularly when the installation must be used when in motion.

Introduction

Not only for the sound recording of concerts, operas, plays and, in short, all program material which is not presented before the microphone in the studio of the broadcasting company, but also for commentaries a mobile installation for sound recording may prove useful, since it is not bound to a single spot during the recording. In constructing a motor van for this purpose in which the sound is recorded by the Philips-Miller sytem [1]) we have attempted to construct an installation which is suitable not only for recording a concert program which makes the highest demands technically, but also for recording commentaries in such a way that they can be broadcast in the radio program at any desired moment with practically the original quality and without the use of telephone lines.

Equipment of the van

Fig. 1 is a general view of the van showing the striking glass turret on the body for the purpose of radio reportage. As may be seen from the plan sketched in *fig. 2*, behind the chauffeur's cabin *B* is the observer's cabin *R*, from which the eye-witness account is given, and next to it the mixing room *M* where the sound which is received from different microphones outside the van comes together to be mixed in the desired way with the remarks of the observer. The rear end of the van is entirely taken up by the recording room *O*, in which the sound is recorded.

By constructing the observer's cabin and the mixing room on a somewhat higher level under the turret (*cf.* fig. 1), and furthermore by introducing a large window in the partition between these two cabins, the observer as well as the sound mixer are provided with as free a view as possible over the

Fig. 1. Motor van for sound recording by the Philips Miller system.

1) Philips techn. Rev. 1, 102, 135, 211 and 231, 1936.

whole surroundings. The observer's cabin is reached through a sliding door in the rear wall of the chauffeur's cabin. The mixing room is, however, connected directly with the recording room in which

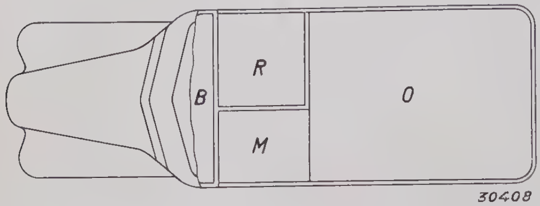

Fig. 2. Plan of the sound recording van. *B* chauffeur's cabin, *R* observer's cabin, *M* mixing room and *O* recording room.

the recording machines are housed with their amplifiers and other necessary apparatus. With this arrangement the sound mixer and the recording technicians are always in communication with each other, while the observer can always enter and leave his cabin without disturbing the technicians.

Because of the higher level of the observer's cabin and the mixing room there is space beneath them for the supply battery necessary when no connection can be made with the alternating current mains, as well as for the cables which make connection with the mains and those which are connected to the microphones set up outside the van. The battery stands in the middle of the space and is flanked on either side by cable drums. This space can be reached from the outside on both sides of the car by means of removable doors provided with ventilation grills. The battery can be reached through traps in the floor of the observer's cabin and the mixing room.

If the sound recording takes place in noisy surroundings or close to the source of sound, it is necessary to provide insulation against sound coming from the outside in order to make possible a good control of the recording. Similarly the sound from the control loud speaker situated in the recording room must be insulated from the outside. In the construction of the body the necessary sound insulation was obtained by covering the walls with two layers of celotex between which a layer of glass wool was introduced. This also improved the acoustics inside the van.

The van is built on a chassis with double rear wheels having a wheel base of 4 m and provided with an 85 h.p. engine. The greatest width is 2 m and the greatest height is 3.20 m from the ground. The total weight is 5 tons. Two steel beams which are part of the body were welded directly to the chassis. The whole installation was then fastened to these beams, and is in this way nowhere connected with the wood of the body. This type of construction insures great stability of the whole installation.

The double doors in the rear end of the van give access to the recording room. These doors are purposely made narrow, each is only 50 cm wide, so that when open they do not extend outside the width of the van, and their swing is limited which makes for economy in parking space.

The turret is provided with double glass windows with panes of different thicknesses, so that they do not have the same resonance frequency and therefore ensure better sound insulation. In order to avoid undesired reflections in the glass the two panes of one window are not parallel. The panes are made of safety glass which may break but does not splinter.

There are no windows in the side walls of the body, in order not to arouse the curiosity of the public who might hinder the work of the technicians. Plenty of light is, however, obtained in the recording room through the glass turret which extends partly over the roof of the recording room, and also through the windows in the rear doors. In the observer's cabin and the recording room

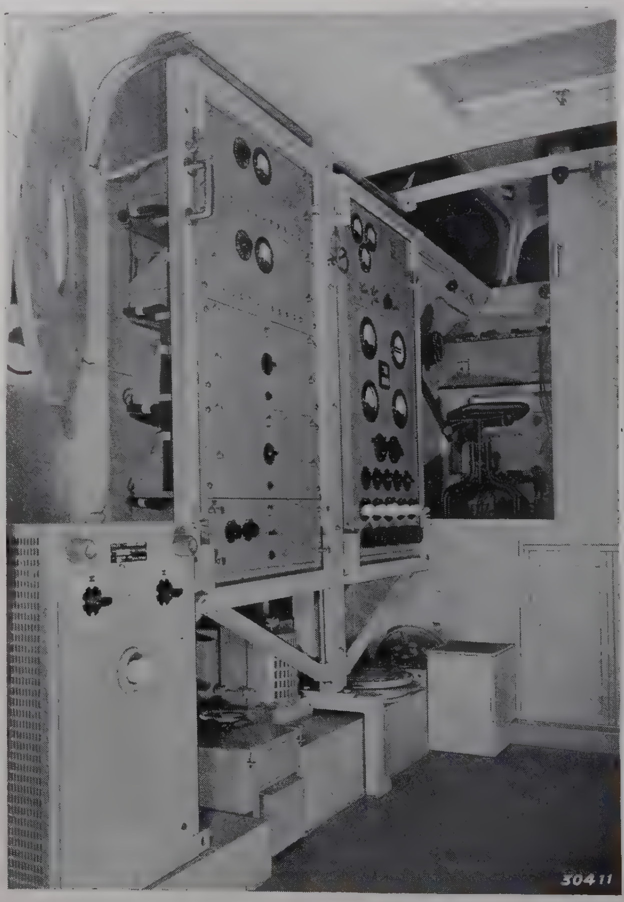

Fig. 3. View of the left side of the recording room showing the opening into the mixing room in the background.

shutters for ventilation have been let into the roof, which can also serve as emergency exits.

In *figs. 3* and *4* may be seen the left-hand and right-hand sides respectively of the recording room. In the background of fig. 3 the communicating door between recording room and mixing cabin may clearly be seen, while at the upper right in fig. 4 the recording machines are visible.

The recording machines

As has already been described in the series of articles in this periodical quoted above, the recording of sound by the Philips Miller system takes place in the following way. A wedge-shaped cutter driven in the rhythm of the sound pressure cuts out a track of varying width in the thin, non-transparent covering layer of a transparent recording film. The reproduction of the sound takes place in the same way as with sound film recorded by the optical method. This method therefore avoids the objections connected on the one hand with the mechanical reproduction of sound recorded on gramophone records, and on the other hand those connected with the optical recording on a sound film. The mechanical recording on

Fig. 4. View of the right side of the recording room showing the two recording machines.

"Philimil" film has the advantages over optical recording, that all operations can take place in daylight, and that the sound track is immediately ready for reproduction without first being developed, while in addition the recording of the high tones is not limited by the size of the photographic grain. As to sound reproduction, "Philimil" film has the advantage that the quality of the sound does not depreciate due to long storage of the film or repeated use, as is the case with gramophone records. Many good copies of "Philimil" film can therefore be made by recording the sound produced by playing it over, while in addition it is also possible, by joining several strips of sound film, to arrange different items one after the other as desired to make a united whole (sound editing).

Since the cutting tool which has been developed for recording by the Philip-Miller system is strongly built and can be combined with the rigid assembly plate of the recording machine to give a strong unit, it is possible to construct an apparatus which is insensitive to shocks, since shocks to the whole apparatus cause no motion of the cutter with respect to the sound track. While in the cutting of gramophone records, shocks do cause difficulties since the cutting pressure must be provided by gravity, the Philips-Miller system is particularly suitable for use in a car when sound must be recorded while riding over rough ground.

The two machines, which may be seen in fig. 4 and one of which is shown in more detail in *fig. 5*, serve not only for recording, but also for reproduction of the sound. Tests have shown that when riding over a rough road, as well as with jolts due to persons stepping in or out or the slamming of doors, a track can be cut with a stationary cutter in this sound recording van which is in no way distinguishable from the track similarly cut when the car is not moving. While in the recording of gramophone records it is absolutely necessary that they lie perfectly horizontal, the Philips-Miller recording machines need not be level, so that slopes of the ground are quite without effect on the performance of this apparatus.

The recording machines are so constructed that it is possible to pass directly from the resting to the working state and *vice versa*. The motor of the machines works continuously, while the transport of the sound film is carried out by a friction gear. When the film is pressed by means of a rubber finger against its support, it can no longer be drawn along, but when the finger is released slightly the friction gear immediately carries it along. The same knob

which switches the film transport on and off also serves to start and stop the cutting action by bringing the cutter in contact with the band and removing it, so that as little time and material as possible is lost in beginning and ending the recording process.

A sound program can be completely put together in this van with the same rapidity as if a special editing table were available, since an electrically heated splicer is set up on one of the recording machines. This is an apparatus which by electrical heating melts the layer of glue on a plaster (*fig. 6*) together with the gelatine of the ends of two pieces of "Philimil" film laid end to end, in order to join them. The recording machines are closed by glass covers to keep them free of dust. This cover is opened in the case of one of the machines in fig. 4. To the left underneath may be seen a sound-insulated box in which is the suction arrangement for removing the shavings produced by the cutter.

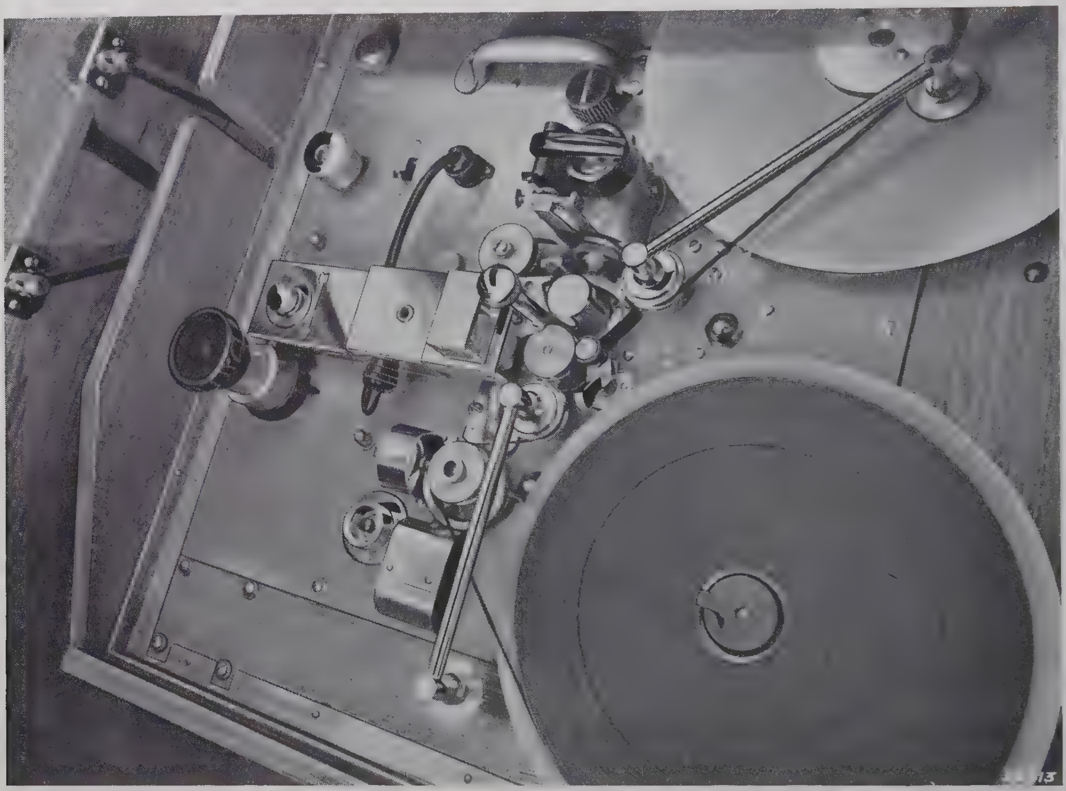

Fig. 5. Detail of a recording machine.

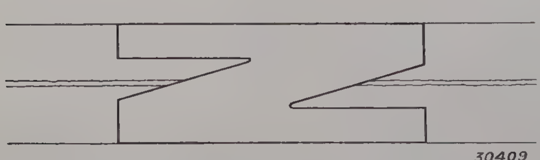

Fig. 6. The plaster with which two pieces of "Philimil" band laid end to end can be joined.

Mixing cabin

In the mixing cabin (*fig. 7*) is housed a mixing amplifier with which the microphone signals are mixed and their intensity regulated. For this purpose a normal line amplifier for radio broadcasting is used. This amplifier has four microphone input channels, two of which are provided with filters. In addition to the main control which determines the volume of the sound, the amplifier has a control with which it is possible to switch over at any moment from the microphone signal to that of the "Philimil" film to be reproduced. This is desirable when it is necessary to transmit, immediately after the recording has been completed, the sound recorded together with the commentary of the observer or announcer; with the help of one of the cables for microphone connections the connection with the telephone network is then made. The amplifier has two output terminals, one of which serves for connection to this transmitting cable, while the other supplies the recorder amplifiers. Such an independent supply prevents them from influencing each other. The end stage of the recorder amplifiers contains a recorder correction filter. For checking the depth of modulation the mixer amplifier is provided with a volume indicator.

This mixer amplifier is fed entirely with alter-

nating current. The supply apparatus is placed in the amplifier panel in the recording room (fig. 3 left-hand panel, bottom). It contains a small audio frequency generator for adjusting the modulation meter and testing the transmission line. The mixer amplifier and the supply apparatus are so constructed that they can be taken out of the van and set up in the theatre or concert hall in which recordings are to be made, and where it is also necessary to be able to see the stage or platform.

Observer's cabin

In the observer's cabin there is plenty of room for two persons so that eye-witnesses can compose the commentary together, and there is also opportunity for questions and answers. By the introduction of a wall covering of celotex, which in turn is partially covered with plates of veneer in order not to make the absorption of the high tones too great, an attempt has been made to adapt the acoustics of the cabin as well as possible to the greatest possible variety of high and low voices of very different timbre. The quality of speech in this cabin is actually found not to be inferior to that in a good speaker's studio.

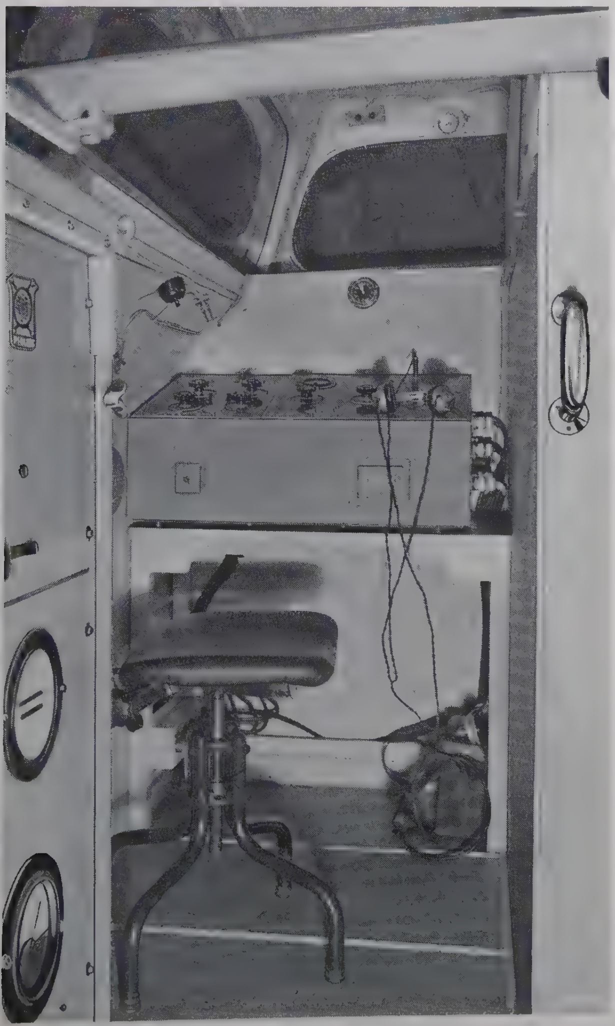

Fig. 7. View of the mixing room.

Amplifier and switch panels

The panel for the recorder amplifier may be seen in fig. 3 on the left and the switch panel on the right. The panels are mounted in a door frame so that they can be opened for inspection. This door frame is fastened directly to the chassis of the car, the panels, however, rest on a number of steel springs.

In the amplifier panel (left) are the two push-pull amplifiers for the sound recording, one above the other, each of which supplies one of the two cutting instruments. Underneath are the two separate supply apparatus, while the lowest compartment of the left-hand panel is occupied by the removable supply apparatus for the mixer amplifier.

The switch panel (right) is occupied by measuring instruments and switches for power supply from alternating current mains, to which the car can be connected by means of a supply cable. This right-hand panel contains a voltmeter, a frequency meter and an ampere-hour meter. There are furthermore a number of switches by which separate parts of the apparatus can be switched on. Underneath is a row of fuses and finally a row of plug connections by which various auxiliary instruments such as a soldering iron can be connected.

The loud speaker amplifier with its control switches and volume control is also mounted in the switch panel. It can be connected as desired to the signal of the mixing amplifier, or to either of the two reproducing machines, or to the output signals of the two recorder amplifiers. In case of an interruption it is therefore possible to localize the trouble immediately. The loudspeaker amplifier can in addition also be connected with the car receiving set when it is desired to record or broadcast sound in the recording van in collaboration with a broadcasting station.

If it is difficult to make connection with the alternating current mains, it is possible to supply the whole installation with the previously mentioned accumulator battery of 40 volts and 270 ampere-hours, with the introduction of a motor generator which gives an alternating voltage of 28 volts which is transformed to the ordinary mains voltage of 220 volts, with which the whole installation is fed. Measuring instruments are introduced to measure the voltage of this supply battery as well as the charging and discharging current.

On the left in the foreground of fig. 3 the rectifier may be seen for charging the supply battery.

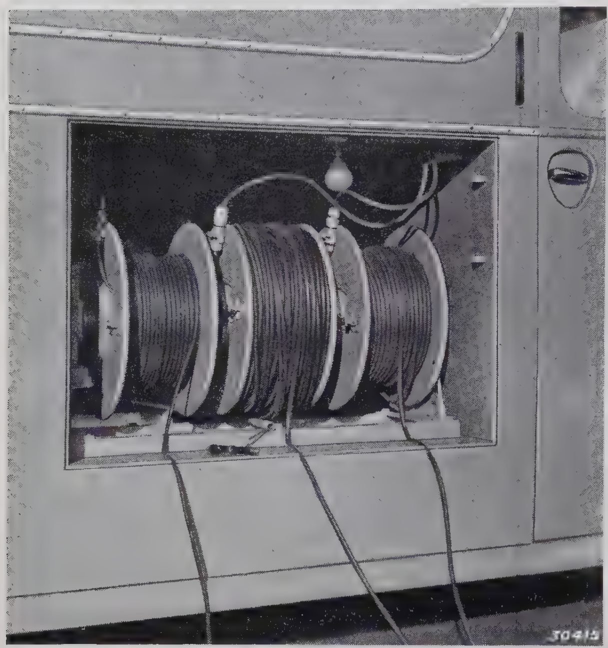

Fig. 8. The cable drums, on a common axle, are kept in the space under the observer's cabin and the mixing room.

When the battery is charged to the normal number of ampere hours the rectifier is automatically switched off. The counting mechanism of the ammeter, whose pointer indicates how many amperehours are still available, is so constructed, in order to ensure that oversaturation is always reached in charging the battery, that it indicates only 3/4 of the number of ampere-hours in the battery during charging, while, it indicates the full number of amperehours used from the battery. The illumination of the car is connected directly to this supply battery.

The different cables for power supply and for the microphone connection are wound on cable drums which may be seen in *fig. 8*. These drums turn on a common axle which is driven by an electromotor *via* a worm gear. As may be seen in the photograph each of the cable drums has a catch by which it is fastened to the axle. 200 m of shielded cable can be stored on each drum, while there are five such drums in the van and the cables can be connected in series.

Compiled by M. J. C. VAN DER MEULEN.

NON-LINEAR DISTORTION IN LOADED CABLES

by G. J. LEVENBACH and H. VAN DE WEG. 621.396.813 : 621.315.054.3

In carrier telephony by the 1+1 system (also with more channels), just as in ordinary low-frequency telephony, coils with magnetic cores are used. The non-linear distortion which results may be more disturbing in carrier telephony in low-frequency telephony because of the intermodulation than of the distortion which occurs in a loaded cable in the case of a single frequency, different measurements of distortion are described, especially in the case of speech, which were carried out on an artificial cable.

In a previous article [1]) it was explained that for constructing a carrier telephone connection a cable is necessary with a sufficiently high cut-off frequency, which means that loading must be applied by means of coils with sufficiently small self-induction. In *table I* the cut-off frequency and the usual self-induction of the coils are given for three cases: ordinary low-frequency telephony, the 1+1-channel system in which one carrier channel is used above the low-frequency speech channel, and the 1+4-channel system in which, in addition to the low-frequency channel, there are 4 carrier channels.

Table I

Cut-off frequency and loading in different telephone systems (section length between two coils = 1.83 km).

System	Cut-off frequency (kilocycles/sec.)	Self-induction of the coils (mH)
Low-frequency telephony	3	177
1+1 system	8	22
1+4 system	21	2.8

The small value of the self-induction for the last case given can easily be obtained with air-core coils. For the coils with high self-induction, however, which are used in low-frequency telephone cables, and also for the 22 mH coils of the 1+1 system, only coils with cores of magnetic material can be used. Air-core coils for this self-induction would (with the same value of ohmic resistance) have very large dimensions; this would cause serious difficulties in connection with the cable boxes, since the cables, especially in low-frequency telephony contain a fairly large number of cores on a traject. Moreover, the spreading of the lines of force is so great with air-core coils that cross-talk between different cores is not easily restricted.

The occurrence of a non-linear distortion in the coils is inherent in the use of cores with magnetic material, because of the non-linear relation between the magnetic induction and the field strength. In low-frequency telephony non-linear distortion in the coils plays no part, since it is much smaller than that which is caused by the microphones. Moreover the harmonics and combination tones occurring as results of the distortion are from the nature of the case not independent of the conversation taking place, and can therefore at the most distort the speech somewhat, but cannot exist as a separate interference. The situation is different in the case of the transmission of more than one frequency band *via* a single conductor, as for instance in the 1+1 system. Part of the distortion products of the coils here falls in the neighbouring frequency band, where it causes a non-intelligible noise which may have an adverse effect on the intelligibility of the conversation.

Therefore, since carrier telephony is more sensitive to non-linear distortion in the coils than low-frequency telephony, it was desirable to investigate in more detail the effect of this distortion. The 1+1-channel system was chosen for this purpose, since it is the simplest one. In the following, after a few theoretical considerations, we shall describe different measurements which were carried out on an artificial cable for this purpose.

Total distortion in a loaded cable

The distortion in a coil due to the non-linear relation between induction and field strength has already been dealt with in this periodical [2]). We shall here recall the conclusions which are important for our purpose. If a current $I = I \cdot \cos \omega t$ is sent through a coil, the magnetic field strength is given by $H = H \cdot \cos \omega t$, The induction B is a non-linear function of H, so that harmonics of ω occur in B. With increasing H, B varies in a different way than with decreasing H, and due to the properties of symmetry of the hysteresis loop traced in a full period all the even harmonics in B fall away. Since the overtones decrease rapidly with increasing order, we need only concen-

[1]) F. de Fremery and G. J. Levenbach, Carrier telephony on loaded cables, Philips techn. Rev. 4, 20, 1939.

[2]) J. W. L. Köhler, Non-linear distortion phenomena of magnetic origin, Philips techn. Rev. 2, 193, 1937.

trate on the lowest overtone present, *i.e.* the third harmonic. By means of Fourier analysis with the help of a simple analytic representation of the hysteresis loop which represents the actual case very well, the amplitude of the third harmonic in the induction can be calculated. By this calculation, the amplitude of the third harmonic of the EMF induced in the coil is found to be

$$E_3 = \frac{3}{5} R_h I_1, \quad \ldots \ldots \quad (1)$$

where R_h is the so-called hysteresis-loss resistance. R_h is given by the formula

$$R_h = K \nu L^{3/2} I_1 \quad \ldots \ldots \quad (2)$$

L is here the self-induction of the coil, ν the frequency and K a constant in which the properties of the material of the core of the coil are accounted for. The 3/2 power of L occurs by the elimination of the number of windings n, because R_h is proportional to n^3, and L to n^2.

According to (1) and (2) E_3 is proprotional to I^2.

Passing on from a single coil to a loaded cable, every coil may be considered as a generator of third harmonics. Due to the damping of the oscillation in its propagation along the cable, however, the contributions of the successive coils to the distortion becomes smaller and smaller, not only absolutely but also relatively; E_3 decreases with the square of I_1. How great will the resulting distortion be at the end of the cable?

Let the cable consist of n—1 sections without the so-called starting section, so that a coil occurs at the beginning and end. Totally, therefore, there are n coils. We imagine the cable to be cut through on both sides of the coil with the index letter p, where the current of the main frequency is $I_{1,p}$, and an EMF

$$E_{3,p} = F I_{1,p}^2 \quad \ldots \ldots \quad (3)$$

to be introduced (F is a proportionality factor) The cable is shut off on both sides in such a way that no reflections occur and the coil is loaded on both sides with the impedance Z of the cable, see *fig. 1*. The current due to $E_{3,p}$ in this section becomes

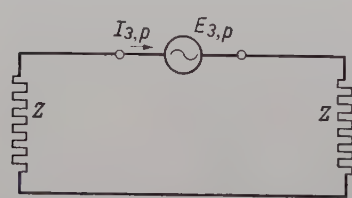

Fig. 1. Each coil (index letter p) gives an EMF, $E_{3,p}$, of the third harmonics. The coil is loaded with 2 Z (Z is the impedance of the cable).

$$I_{3,p} = \frac{E_{3,p}}{2Z} = \frac{F I_{1,p}^2}{2Z}.$$

If a is the damping per section of cable, and thus e^{-a} the relation of the current at the beginning and end of the section, then $E_{3,p}$ gives at the end of the cable the current contribution

$$I_{3,n} = I_{3,p} e^{-(n-p)a} \quad \ldots \ldots \quad (4)$$

We shall assume that the frequencies of the main wave and of the third harmonics both still lie in the "flat" part of the frequency characteristic of the cable, so that both experience the same damping. Then the current from the main frequency at the end of the cable is

$$I_{1,n} = I_{1,p} e^{-(n-p)a} \quad \ldots \ldots \quad (5)$$

We thus obtain

$$I_{3,n} = \frac{F}{2Z} I_{1,n}^2 e^{(n-p)a} \quad \ldots \ldots \quad (6)$$

Adding all the current contributions due to the coils $p = 1$ to $p = n$ gives the total current of the third harmonic at the end of the cable:

$$\Sigma I_{3,n} = \frac{F}{2Z} I_{1,n}^2 \sum_{p=1}^{n} e^{(n-p)a}.$$

On the right-hand side of this equation is a geometrical series with the ratio e_a, whose sum is given by the formula:

$$\sum_{p=1}^{n} e^{(n-p)a} = e^{(n-1)a} \frac{1-e^{-na}}{1-e^{-a}}$$

If the number of sections is so great that we may neglect e^{-na}, with respect to 1 and further if a is so small that $e^{-a} \approx 1-a$ (both conditions are well satisfied in practice) then

$$\Sigma I_{3,n} = \frac{F}{2Z} I_{1,n} \cdot \frac{I_{1,n} e^{(n-1)a}}{a} \quad \ldots \quad (7)$$

In this expression we substitute for $I_{1,n} e^{(n-1)a}$ the current $I_{1,1}$ at the beginning of the cable and further for $F \cdot I_{1,1}$, 3/5 R_{h1} (see equations (3) and (1)):

$$\Sigma I_{3,n} = \frac{3 R_{h1}}{10 a Z} I_{1,n} \cdot \quad \ldots \ldots \quad (8)$$

The logarithm a_h of the relation between the absolute value of $I_{1,n}$ and $\Sigma I_{3,n}$ is called the distortion damping [3]):

$$a_h = \ln \left| \frac{10 a Z}{3 R_{h1}} \right| \text{ nepers} \quad \ldots \quad (9)$$

(In order to obtain a_h in decibels the value calculated must be multiplied by 8.69).

The quantity a_h indicates how large the amplitude of the main frequency is at the end of the

[3]) W. Deutschmann, El. Nachr. Techn. 6, 80, 1929.

cable with respect to the harmonics; it thus provides a measure of the disturbing effect of the distortion by the coils.

The distortion damping

In the above derivation, in addition to the simplification that the same damping constant was used in (4) and (5), the fact is also neglected that the current contributions (6) to be added may have a phase shift [4]). Furthermore in (7) the cable is assumed to be very long. All these simplifications influence the result in the same direction: they make a_h smaller, *i.e.* the distortion greater. Therefore a practical case can never be worse than the result given by formula (9).

It may be seen from this formula that in the first place the distortion becomes less when the damping a is made greater, for instance by choosing a smaller core diameter. In practice this possibility will not generally be made use of, since the core diameter is already fixed by other considerations.

Furthermore a_h also becomes smaller with increasing R_{h1}. Since R_{h1} is proportional to $I_{1,1}$ (equation (2)), this means that, the distortion becomes worse with increasing transmission level at the beginning of the cable. This relation is represented graphically in *fig. 2.* The permissible distortion determines how high the transmission level may be raised. The relation drawn is however valid only for a definite value of the proportionality factor between R_h and I_1, thus of the factor $K\,\nu\,L^{3/2}$ in equation (2). Since in practice it is only possible to influence the value of K, namely by the choice of a suitable core for the coils, the coil is characterized by giving the value of $R_h/L^{3/2}$ at a definite frequency ν and current I. It is customary to choose $\nu = 800$ cycles and $I_1/\sqrt{2} = 1$ mA (effective current): the value of $R_h/L^{3/2}$ thereby measured is called the hysteresis factor (q_2).

For a definite distortion, *i.e.* for a definite value of R_{h1}, the transmission level ($I_{1,1}$) can be chosen higher, the smaller the hysteresis factor. Since the transmission level helps to fix the necessary distance between repeaters [6]), it is important to keep the hysteresis factor as low as possible. The C.C.I.F. (Comité consultatif international des communications téléphoniques à grande distance) prescribes that the hysteresis factor q_2 of coils for the 1+1 system may amount to 6 ohms/henry$^{3/2}$ at the most, while coils for low-frequency telephony, where the distortion of the coils causes little difficulty, may have a q_2 equal to 12. If for the 1+3 or 1+4 system, where the distortion is even more disturbing than in the 1+1 system, it is also desired not to use air-core coils, but coils with magnetic cores, a value of q_2 less than 3.3 is required.

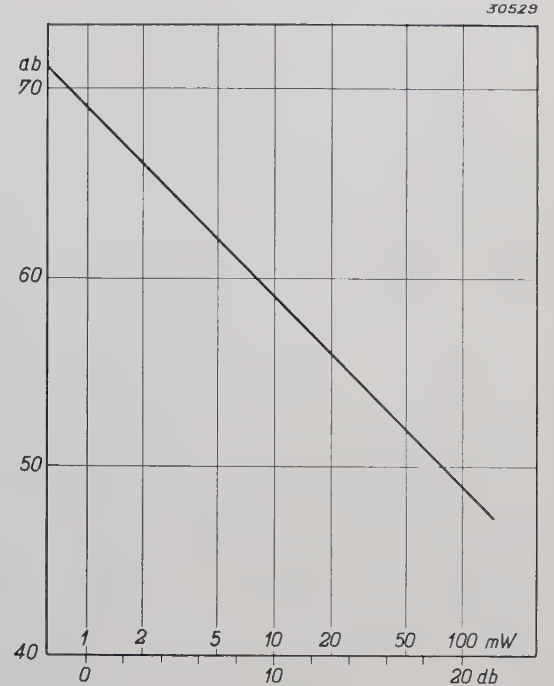

Fig. 2. Distortion damping a_h (in dB) as a function of the transmission level (in mW), according to formula (9) due to Deutschmann. $Z = 600$ ohms $a = 0{,}4$ dB.

Measurement of the distortion damping

In the calculation of the distortion given above a sinusoidal signal was assumed. The case where the signal contains two frequencies is in general impossible to calculate due to the fact that the hysteresis loop traced takes on a very complex shape. The case of speech is still less amenable to theoretical treatment. In order to find out to what degree the distortion of speech follows a course analogous with the simple case considered above, measurements were carried out on an artificial cable. This consisted of 20 sections which had the same resistance and capacity as a cable with a core diameter of 1.3 mm, and was loaded with coils of 22 mH. The low-frequency channel contained the frequencies from 300 to 2 700 c/s, the carrier-wave channel those from 3 300 to 5 700 c/s.

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[4]) More precisely stated: it is assumed that the waves of the third harmonic have the same transit line as the main wave. For this the shift in phase angle must be proportional to the frequency (see the article in footnote 1 on pages 24, formula (6) and following). This is approximately true for a not too great frequency range.

[5]) The factors mentioned can also be taken into account in the calculation. In this way a more exact formula has been derived by K. E. Latimer, Intermodulation in Loaded Cables, El. Comm. 14, 275, 1935/36. Formula (9) is adequate for our purpose.

[6]) See the article quoted in footnote 1 on pages 25 and 26.

Measuring arrangement

The measuring arrangement used is represented in *fig. 3*. At the input side of the artificial cable K the speech vibrations from the low-frequency channel were admitted. A low-pass filter L is therefore connected in series here, which cuts off frequencies above 2 700 cycles. The total voltage at the output side of the cable (main-frequencies and new frequencies originating in the cable) is, in position I of the switches, fed to a voltmeter V over a constant damping D_c of 40 dB and a variable attenuator D_v. In position II of the switches the current first flows through a bandfilter B which only passes the carrier-wave channel, *i.e.* the frequencies from 3 300 to 5 700 c/s originating in the cable. In both positions the variable attenuator is adjusted until the voltmeter gives the same deviation A. The difference between the two adjustments of the damping increased by the constant is also necessary at the beginning of the cable: at the low-pass filter the higher frequencies formed in the cable would be reflected and this would render the result of the measurement incorrect. The low-pass filter now receives ten times the power which is applied to the cable. Care must therefore be taken that no harmonics can originate in the coils of the filter, which harmonics, due to the great difference in power, might be comparable with the overtones formed in the cable. Because of this possibility air-core coils are used in the filter. By measuring the distortion damping of the apparatus without cable, it was ascertained that the results of the measurement were not influenced by non-linear distortion in other elements.

Measurements

With the help of this arrangement various measurements were carried out, beginning with

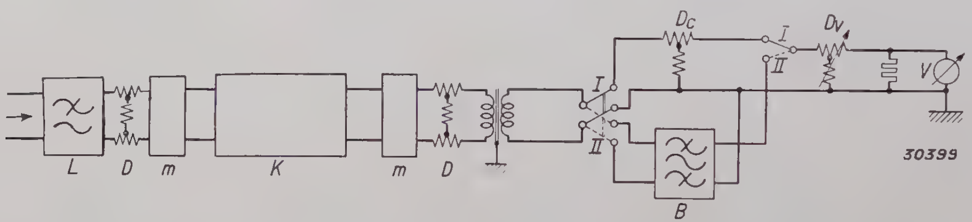


Fig. 3. Arrangement for measuring the distortion damping of a cable. K artificial cable of 20 sections; m, m-sections, D damping sections, L low-pass filter for 300 to 2 700 cycles, B band filter for 3 300 to 5 700 cycles, D_c constant damping of 40 dB, D_v variable attenuator, V voltmeter.

damping difference of 40 dB gives the required distortion damping a_h.

Special attention had to be paid here to the termination of the cable at both ends. In order to be able to terminate the cable with an ohmic resistance, a so-called m-section (m) is connected at the beginning and end of the cable. The terminating resistance can then be 600 Ohms, which was desired in connection with the measuring apparatus. If the band filter were now connected directly to the cable in position II of the switches, the main frequencies of 300 to 2 700 cycles would here undergo strong reflection, since the band filter has no real impedance of 600 ohms in this frequency region. The current distribution in the sections of the cable, and with it the contribution to distortion of the separate coils due to the dependence of R_h on the current, would be affected by the reflected waves. Therefore at the end of the cable another constant damping D of about 10 dB is added to the circuit; the reflected waves which return into the cable are attenuated by 20 dB and thus no longer have any appreciable effect. For similar reasons a damping of 10 dB

one frequency, namely 1 500 c/s. This lies just in the middle of the region of frequencies (1 000 to 2 000 c/s) whose third harmonic falls in the carrier-wave channel. The distortion damping was determined as a function of the power applied to the beginning of the cable. The results are represented in *fig. 4*. The continuous line I was measured, the broken line was calculated according to equation (9) for the same values of a, Z and q_2. The measured distortion is smaller than the calculated, which was to be expected from the above explanation. The deviation here may be ascribed chiefly to the fact that the number of sections was too small compared with that of a real cable, namely not large enough for the simplification introduced into equation (7).

The measurement was repeated with another value of q_2, *i.e.* with a set of loading coils with different cores. The continuous line II in fig. 4 gives the result, q_2 had about the value 4 in the case of line I, in the case of line II it had about the value 18. According to equation (9) this relation must correspond to a difference of 13 dB in the distortion damping, while according to fig. 4 a difference of

about 14 dB was measured. Considering the accuracy [7]) which can be attained in the measurement of q_2 and the inevitable lack of uniformity in material properties the agreement is satisfactory.

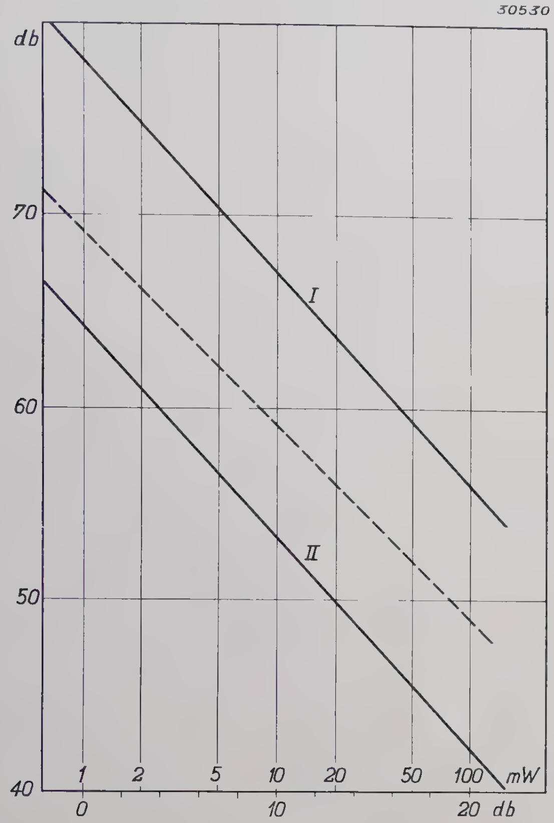


Fig. 4. Distortion damping a_h in the case of one frequency (1 500 cycles/sec) as a function of the transmission level. The continuous lines are measured, the broken line calculated by formula (9) for the same values of a, Z and q_2 as in line *I*. Lines *I* and *II* are recorded at different values of q_2; *I*, $q_2 = 4$; *II* $q_2 \approx 18$.

In distortion measurements on speech the greatest difficulty is the determination of the level of speech. The average power might be determined by means of a measuring instrument with very great inertia. This average value may be useful for judging the level of the speech of a given speaker, but it has however no direct significance for the distortion, since intermodulation, cross-talk between different channels, is due exactly to the peaks. By the C.C.I.F. the speech level is defined as follows. The voltmeter is calibrated with a voltage. The deflection which is exceeded once in three seconds during the measurement of the speech indicates the level of speech. The voltmeter used must have an integration time of 0.1 sec., *i.e.* within this time it must indicate the final value accurately to 2 dB in the case of a constant voltage.

In order to obtain a reproducible transmission level speech was recorded on a gramophone record. During the recording a voltmeter with high inertia was placed next to the microphone, so that the speaker could check the volume of his voice and could keep it as nearly as possible constant (see above). When the record was reproduced the speech was fed to the artificial cable over an adjustable amplifier, so that the transmission level could be regulated at will.

In practice the determination of the transmission level is as follows. A sinusoidal voltage of known power, 1 mW for example, is fed to the cable with the switches in position *I* (see fig. 3). With the help of the variable attenuator the deflection of the voltmeter was adjusted at a value *A*, for which a damping of a_1 is necessary, for example. Then with a definite, temporarily unknown transmission level the speech is fed to the cable. The number of voltage peaks is now counted which extend beyond the deflection *A*. When the record is finished the counting is repeated several times, each time with a different value of the variable damping in the circuit. If the number of peaks per second is

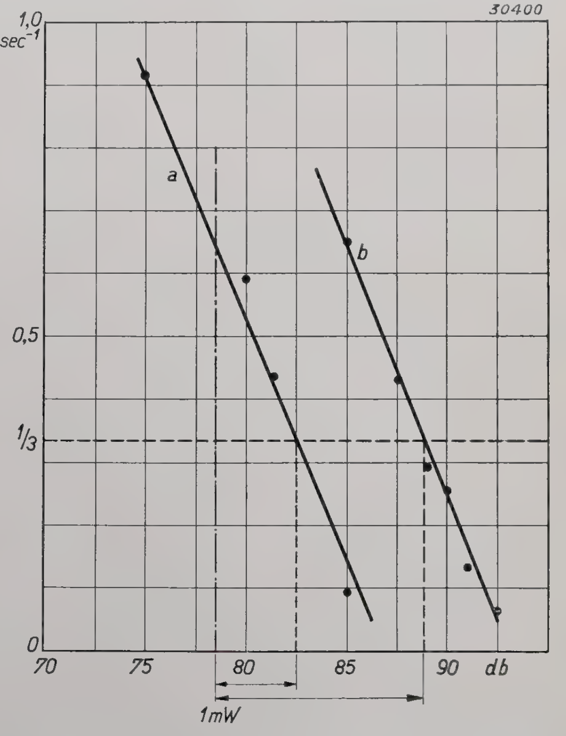


Fig. 5. Number of peaks per second during the reproduction of a record of speech, as a function of the damping in the circuit (*Dv* in fig. 3). The zero level indicated by a line thus .—.—. is that of a sinusoidal voltage of 1 mW. The level of speech is determined as the level which is exceeded once in 3 sec. For every transmission level of the speech a line is obtained like the one here drawn for two values of the transmission level. With line *a* it is found from the figure that the transmission level is 2.5 mW, with line *b* it is 11 mW.

7) The hysteresis factor q_2 is measured as the difference between the values of the coil resistance with two different currents. Since the hysteresis-loss resistance is very small compared with the total resistance a small error in absolute value in the measurement of the resistance gives quite a large relative error in the value of q_2. In series measurements an accuracy of the order of 5% can be attained.

plotted as a function of this damping, see *fig. 5*, this damping a_2 can be found by interpolation at which A is exceeded once in 3 seconds. The difference between a_2 and a_1 in dB indicates how many dB the transmission level of speech lies above 1 mW.

This process is repeated after the switches are put in position *II*. The level of the non-intelligible noise caused by the distortion products in the carrier-wave channels is thus measured. A damping a_{2v} is found at which the deflection A is exceeded once in 3 seconds and the difference between a_2 and a_{2v} gives the distortion damping a_h corresponding to the transmission level.

The measurement is thus quite elaborate: to obtain one measured point it is necessary according to the above to play over the record of the speech a fairly large number of times.

Fig. 6 shows the relation recorded in this way between distortion damping and transmission level for a given speech record. With a different speech record of the same speaker a line was found which deviated nowhere by more than $^1/_2$ dB from the one with the first record.

By means of the relation drawn it can now be determined how high the transmission level can be raised in practice without exceeding the permissible distortion. If, for example, a distortion damping of at least 65 dB, (C.C.I.F. Oslo 1938), is required, it follows from fig. 6 that the transmission level may be 5 mW.

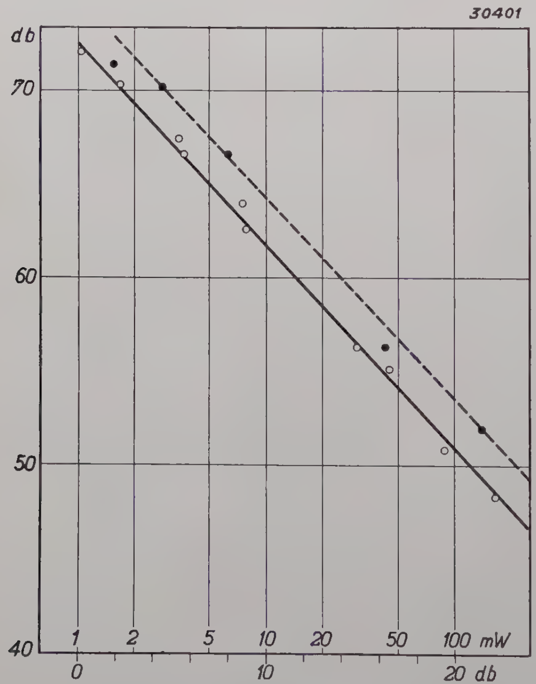


Fig. 6. Distortion damping measured for speech, as a function of the transmission level. Continuous line: speaker with a heavy voice, broken line: speaker with a lighter voice. By means of such a curve the transmission level is determined in connection with the permissible distortion damping.

The same measurements carried out with gramophone records of a speaker with a lighter voice gave the broken line in fig. 6. The distortion is smaller here than with the first speaker. This may be explained from the fact that in the case of the speaker with the lighter voice the peaks in the speech energy occur relatively more often at tones with frequencies above 2 000 cycles. These peaks contribute less to the distortion observed, since the third harmonics and different combination tones of these frequencies fall outside the carrier-wave channels.

The voltmeter with which the measurements are done integrates over the energy contribution of all frequencies. The measurements therefore do not give a direct measure of the physiological impression of the distortion; in practice all the frequencies will not contribute to the same degree to the disturbance, since the oscillations first undergo the influence of the frequency characteristics of the telephone and of the ear. This can be taken into account by taking for the measurement a socalled "psophometer", by which the influence of the telephone and the ear are imitated by a filter in series. We have not done so in order to make it easier to compare the meaurements with the theory.

Finally it might still be asked whether, due to the insertion of the gramophone record in the natural course of events, too great a compression of the speech intensities does not occur which might invalidate the measurement of the distortion; it is just the peaks, which are most damped upon compression, which play the greatest part. The nature of speech can in this respect be characterized by the slope of the curves as given in fig. 5. Beginning with the level which lies just above the highest peaks in speech, and which is therefore never exceeded, it has been shown in measurements by Fletcher [8]) that in normal speech the level lying 3 dB lower is exceeded once in $6^1/_4$ sec., and that lying 11 dB lower once in $1^1/_4$ sec. The slope determined by these measured points agrees very well with that of the measured lines in fig. 5. The character of speech, as far as causes of distortion are concerned, is therefore not falsified by the gramophone [9]). The noise of the needle of the pick-up can have no unfavourable effect on the results of the measurement since it is almost completely removed by the low-pass filter at the beginning of the cable.

[8]) H. Fletcher, Bell Syst. Techn. J. **10**, 349, 1931.

[9]) In practice it must be taken into account that a limitation of the amplitude always occurs at the beginning of the cable (by the so-called limiter), which limitation corresponds to a certain compression.

APPLICATION OF CATHODE RAY TUBES IN MASS PRODUCTION

by H. van SUCHTELEN.

621.317.755

Two examples are discussed of cases in which the cathode ray oscillograph makes it possible to adapt an otherwise rather complicated measurement to the tempo of mass production. The examples refer to the checking of the resonance curve of radio receiving sets and the detection of defects in the windings of motor or dynamo armatures.

There are various considerations which may make the use of a cathode ray oscillograph advisable. An obvious case is that of a measurement requiring an instrument with no inertia, as for example the recording of a dynamical characteristic referring to a periodic phenomenon. The oscillograph is also a welcome aid in increasing the speed of measurement when a static measurement would injure the object being measured, or when it is a question of carrying out check measurements in a rapid tempo. This latter use may be of special importance in mass production. We shall discuss here two examples in which the cathode ray oscillograph makes it possible to adapt an otherwise fairly complicated measurement to the tempo of mass production.

The measurement of resonance curves of radio receiving sets

The resonance curve of a receiving set gives the voltage on the detector as a function of the frequency difference between the tuning of the set and the frequency of a signal which is fed in on the aerial side with a constant amplitude. The curve is important, since it indicates decisively the selectivity of the receiver, and thus the degree to which an interfering transmitter with a frequency differing from the tuning frequency is suppressed. Moreover the difference in reproduction between the carrier wave and the side bands due to modulation may be read off from the curve. Although a sharp resonance curve ensures good selectivity, it nevertheless cuts out of the frequency spectrum received those side bands which correspond to the high frequencies in the modulation [1]). The compromise which may be made leads to a resonance curve which has been rather accurately determined. If it is not desired to keep to this compromise, there is also the possibility of adjusting the set so that the shape of the resonance curve can be changed at will. In such a case one speaks of sets with variable band-width.

From this it follows that the measurement of the resonance curve during manufacture of a set, or after repairs have been made on a set, is important. In order to make the rapid recording of this curve possible a special apparatus has been developed by Philips, the frequency modulator GM 2881, which, in combination with a cathode ray oscillograph, permits immediate inspection of the whole resonance curve.

Principle of the measurement

It is obvious that in the first place a source of high-frequency voltage must be available which gives the same frequency as that to which the receiver being tested is tuned, but whose frequency in a region on either side of the tuning point can be varied. At each frequency the voltage on the detector of the receiving set is measured. A directly visible diagram results when this voltage is registered in a vertical direction on the screen of an oscillograph, and when at the same time care is taken that there is a horizontal deviation proportional to the variation in the frequency. In order to obtain a lasting image on the screen, this process must be repeated rapidly (50 times per second for instance). The frequency of the incoming signal thus "wobbles" back and forth about its mean value, and the frequency modulator which causes it to do so is called a "wobbulator" to use an Americanism.

In the apparatus here described the normal oscillograph GM 3152 or the smaller one GM 3153 were used. In these oscillographs a sawtooth auxiliary voltage is generated which provides the horizontal deflection of the light spot. In order to obtain a fixed relation between the horizontal deflection and the measuring frequency the sawtooth voltage must also control the frequency modulator. This can be realized with various circuits, one of which is shown diagrammatically in *fig. 1.*

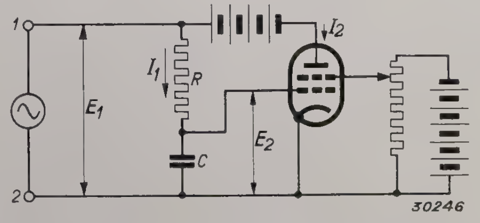


Fig. 1. The voltage E_1 causes a current through the valve $I_2 = E_1 \cdot S/j\omega\, C\, R$, so that the circuit is equivalent to a self-induction L having the value CR/S. By regulation of the slope of the valve S the value of this equivalent self-induction can be varied.

[1]) See also C. J. van Loon, Philips techn. Rev. 1, 264, 1936.

In this circuit if R is large enough compared with $1/\omega C$, an alternating voltage E_1 between the terminals *1* and *2* will cause a current I_1 to flow which is practically equal to E_1/R. This current causes a voltage on the condenser C,

$$E_2 = I_1 \frac{1}{j\omega C} = \frac{E_1}{j\omega C R},$$

which is 90° in phase behind E_1. The voltage E_2 acts on the control grid of a multiple-grid valve whose anode current I_2 therefore becomes

$$I_2 = S\, E_2 = E_1 \frac{S}{j\omega C R}.$$

S is here the slope of the valve.

If instead of the circuit drawn we had simply connected a self-induction L to terminals *1* and *2*, the current in it would have become

$$I_2 = E_1 \frac{1}{j\omega L}.$$

The circuit is therefore equivalent to a self-induction of the value

$$L = \frac{C R}{S}.$$

This equivalent self-induction can be influenced by changing the slope of the valve, which can easily be done by varying the voltage on one of the other grids. In fig. 1 the voltage on the second grid is assumed to be adjustable.

The circuit of fig. 1 therefore finally gives an equivalent of a self-induction whose value can be varied by an applied control voltage. If such a circuit is now included as a part of the total self-induction in an oscillating circuit, the characteristic frequency of this circuit is in turn influenced by the control voltage applied. If we use for this voltage the sawtooth voltage of the cathode ray oscillograph, we have in principle a solution of the problem.

A certain horizontal deflection of the light spot now corresponds to a certain variation ΔL in the total self-induction of the oscillating circuit with which the frequency to be supplied is tuned. For the characteristic frequency f of this circuit the following holds:

$$f = \frac{1}{2\pi\sqrt{LC}},$$

from which it follows that

$$\frac{\Delta f}{f} = -{}^1/_2 \frac{\Delta L}{L}.$$

If it is now desired to record the resonance curve of the receiving set at different tuning points, it would seem reasonable to regulate the characteristic frequency f correspondingly, for instance by means of a rotating condenser. If this were done, however, the a b s o l u t e frequency fluctuation on both sides of the tuning frequency for a given horizontal deflection of the light spot would become very different for different tunings, since, according to the above formula, the p e r c e n t a g e frequency fluctuation $\Delta f/f$ remains constant. For example, in the recording of the resonance curve at 100 kilocycles and at 1 000 kilocycles the width of the diagram obtained in kilocycles would be 10 times as small in the first case as in the second. This is undesirable. In practice it is desired always to command the same frequency range of for instance 50 kilocycles.

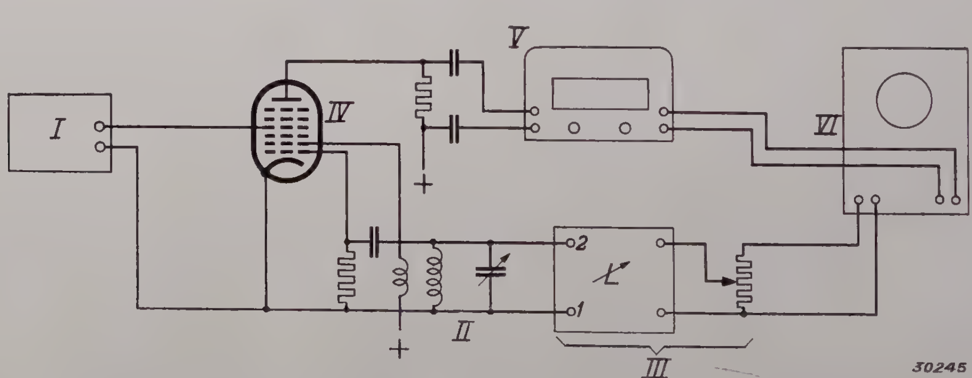


Fig. 2. Arrangement for recording resonance curves. The receiving set to be investigated, V, is tuned in for instance on 1 000 kilocycles. The signal generator I is then adjusted to a frequency of 5 000 kilocycles. The self-oscillating circuit II has a fixed output frequency of 4 000 kilocycles, so that in the frequency changer IV a frequency difference of 1 000 kilocycles occurs which is fed to the receiver. The frequency of circuit II is influenced by the equivalent self-induction III in parallel with it (circuit according to fig. 1), which is controlled by the sawtooth voltage from the cathode ray oscillograph VI. The frequency of II therefore "wobbles" 50 times per second, for instance, by an amount of 50 kilocycles about its fixed mean value of 4 000 kilocycles. The frequency of the signal fed to V therefore exhibits the same fluctuation, so that the oscillograph which measures the detector voltage of V gives a lasting picture of the whole resonance curve.

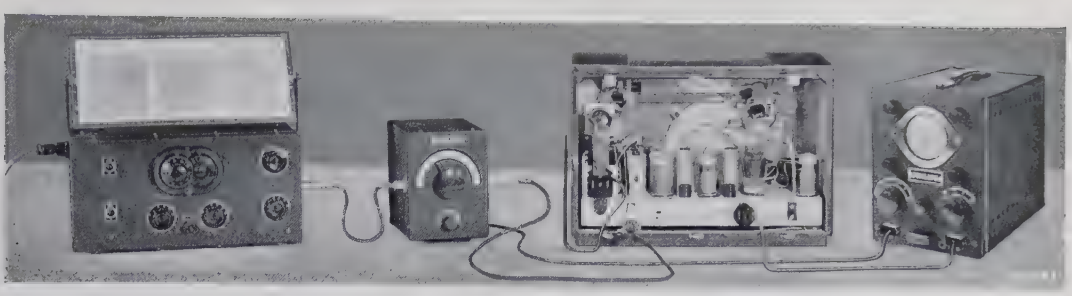


Fig. 3. Photograph of the arrangement according to fig. 2. The components *II*, *III* and *IV* there shown are combined into one apparatus, the frequency modulator GM 2881.

Therefore the frequency modulator is designed for a constant average frequency *f*, and the desired measuring frequency is obtained by adding another non-fluctuating frequency according to the well-known superheterodyne principle.

Measuring arrangement

On the basis of the above an arrangement is arrived at as shown in *fig. 2*. Let us assume that the receiver to be examined, *V*, is tuned at 1 000 kilocycles. A signal of this frequency is obtained by mixing in valve *IV* a signal of 5 000 kilocycles from a normal signal generator *I*. (GM 2880) and an oscillation of 4 000 kilocycles from the self-oscillating circuit *II*. In parallel with the latter is introduced a circuit similar to that in fig. 1 (*III*), which is controlled by the sawtooth voltage from the oscillograph *VI*.

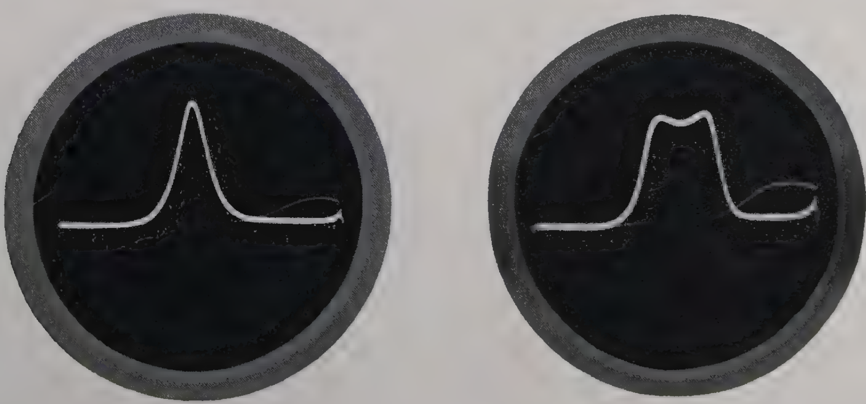
The equivalent self-induction of *III* is large with respect to that of circuit *II*; the connection in parallel therefore has relatively little influence on the circuit. Since, however, its original frequency is quite high (4 000 kilocycles), the fluctuations in kilocycles are still of the order of 50 kilocycles.

If it is desired to measure the resonance curve of the receiving set *V* at another tuning, the frequency of the oscillator *I* must be so changed that it always lies 4 000 kilocycles above the tuning frequency of *V*.

When a suitable modulator valve is used in the circuit of fig. 1 a practically linear relation between the frequency variation and the control voltage can be obtained within sufficiently wide limits. The diagram on the screen then has a linear frequency scale. In order to calibrate the size of this scale rapidly a simple device has been introduced into circuit *II*. This circuit is tuned by means of a variable condenser provided with a scale calibrated in kilocycles. In this way it is possible to alter by a known amount the original frequency of 4 000 kilocycles which corresponds to the original position of the light spot on the screen. By this means the image on the screen is displaced over a distance which corresponds to the number of kilocycles change in tuning. It is therefore only necessary to measure the displacement in order to determine the number of mm for 1 kilocycle.

The control voltage obtained from the oscillograph may first be reduced in *III*. Then with the same horizontal deflection a smaller variation of frequency is obtained, in other words, the frequency scale of the diagram is changed.

In the practical construction, components *II*, *III* and *IV* of fig. 2 are combined in one apparatus,



a b

Fig. 4. Resonance curve of a receiving set with adjustable band width; a) adjustment on "narrow"; b) adjustment on "wide".

GM 2882. This may be seen in fig. 3 in the second place between the signal generator GM 2880 and the receiver to be tested. The small oscillograph GM 3153 is also included in the set-up.

Records of the voltage on the detector obtained with this apparatus are shown in *figs. 4a* and *b*. Both records were with a receiving set with adjustable band width. Fig. 4*a* gives the resonance curve at the "narrow" adjustment, fig. 4 *b* that at "wide" adjustment. In the last figure the typical "shoulders" may be seen which occur with so-called over-coupled band filters.

When the oscillograph GM 3152 is used, which can take care of very high frequencies, there is the possibility of tapping off the voltage of the receiving set even in front of the detector, which may sometimes be desirable. A linear diagram is then not formed, but a surface filled by the high-frequency oscillation, as in *fig. 5*. This last diagram was recorded on a receiving set with a rejector filter for the suppression of an interfering transmitter close to the tuning point of the set. It may be seen very clearly how the amplitude is suppressed for the frequency in question.

Fig. 5. Resonance curve of a receiving set with rejector filter in series for suppressing an interfering transmitter close to the tuning point. The voltage measured is here tapped off in front of the detector of the receiver, so that the surface of the diagram is filled by the high-frequency oscillation.

Measurement of resistance on motor or dynamo armatures

After a collector armature has been wound it must be tested to see whether any of the coils of which the winding consists has a short circuit or a break. Such defects may easily occur during the soldering of the ends of the coils to the lamina of the collector. In the case of small armatures, for example, 20 measurements of a resistance must be carried out in this testing. In mass production, as in the manufacture of vacuum cleaners, sewing machines, starter motors, etc. it is important to save time in the checking measurements. The following method has been worked out for this purpose.

When the resistance is measured by being read off a dial instrument, it is customary to place two contacts on the collector in such a way that the resistance is measured between two successive laminae. The collector is then turned slowly under the contacts so that the different coils are measured in turn. The tempo is determined by the time necessary for the meter to come to rest and be read.

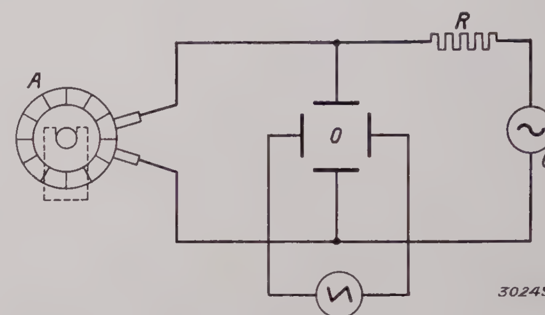


Fig. 6. Circuit for the testing of collector armatures. Two measuring contacts are placed on two adjacent laminae of the collector. The oscillograph O is connected between these contacts and in parallel with it over the resistance R the signal generator G (built into the Philips oscillograph GM 3153). The resistance R is about equal to the impedance of one coil of the armature winding. If the armature runs synchronously with the time base of the oscillograph, a stationary diagram is obtained which makes it possible to inspect the condition of the whole armature.

The cathode ray tube, which is a measuring instrument with no inertia, permits much more rapid measurement, and moreover it is possible to record a diagram of the resistance as a function of the point on the collector, and thus to see at a glance the condition of the whole armature.

This idea may be realized in a very simple way with the help of the Philips oscillograph GM 3151. For practical reasons the impedance is measured instead of the usually quite low resistance. For this purpose a small alternating voltage generator of 10 000 cycles is used and built into the oscillograph. This generator is connected over a resistance R to the measuring contacts which are placed on the collector, and which are in parallel with the oscillo-

a b

Fig. 7. Records of two motor car dynamos.
a) The armature is in order
b) The armature has a short circuit.

graph plates, see *fig. 6*. If R is about the order of magnitude of the impedance of one coil, then the voltage on the oscillograph becomes one half the generator voltage. If there is a break in a coil the voltage becomes equal to the generator voltage, with a short circuit it becomes zero. This rough indication of the impedance in the winding is sufficient for testing an armature.

For a rapid measurement the armature is placed in half bearings and driven by a friction disc. It is then also possible to provide for a linear time base on the screen of the oscillograph in the ordinary way. If the sawtooth frequency is chosen equal to the number of revolutions of the armature, a given horizontal deflection corresponds to the passing of a given pair of laminae under the contacts.

In *figs. 7a* and *b* are two records made of motor car dynamos. The armature *a* was normal, *b* had a short circuit. A defect is detected in this way in the time which would otherwise be necessary for the measurement of one coil. It is of course possible to detect short circuits between the laminae and the mass of the armature in the same way.

ABSTRACTS OF RECENT SCIENTIFIC PUBLICATIONS OF THE N.V. PHILIPS' GLOEILAMPENFABRIEKEN

1339: J. L. Snoek: Time effects in magnetization (Physica **5**, 663-688, Aug. 1938).

A theory is proposed for the mutual magnetic action of long duration and for the reversible decrease in permeability (disaccomodation). These two phenomena are considered to be caused by the elastic after-effect which occurs due to magnetostriction in the boundary surfaces of the Weiss regions.

This theory is found to be capable of explaining qualitatively all the phenomena observed up to the present. Moreover, the theoretical conclusion that the two phenomena can only occur simultaneously (although in different temperature ranges) is confirmed by investigations of the authors. If the elastic after-effect is described by a single extinction time, and if it is further assumed that the Weiss regions have mutually identical properties, it is possible to set up elementary formulae for the two effects in which the reciprocal value of the permeability plays an important part. The formula for the reversible decrease in permeability is then found to be in good agreement. In the formulae for the magnetic after-effect a longer extinction time is found to occur. The formulae, however, are not strictly valid since the parameters occurring in them take on different values in different Weiss regions. Nevertheless the after-effect theory agrees satisfactorily with experiment.

1340: M. J. O. Strutt and A. van der Ziel: On electronic space charge with homogeneous initial electron velocity between plane electrodes (Physica **5**, 705-717, Aug. 1938).

In this discussion of the space charge phenomena between parallel electrodes due to electrons which all leave the cathode with the same speed, the electrons which return to the space between grid and anode because of the space charge are not neglected as soon as they have left the space. Part of these electrons return a second, third, etc. time to the space between the grid and anode, and therefore have a strong influence on the variation of voltage and current at that place. The possible forms of these curves are studied as fully as possible for a number of cases.

1341: K. F. Niessen: Ueber die Phase des Magnetfeldes (Physica **5**, 769-774, Aug. 1938).

Because of the fact that several textbooks fail to carry out calculations consistently with the correct phase of the magnetic field, and fail to apply correctly the limiting conditions of Maxwell (for example in the case of receiving aerials), several fundamental calculations are discussed critically with this in mind.

1342: R. Vermeulen: Das Philips-Miller-System zur Tonaufzeichnung (Akust Z. **3**, 65-73, Mar. 1938).

A short survey is given in this article of the Philips-Miller system of sound recording, for which we may refer to a series of four articles in the first volume of this periodical (Philips techn. Rev. **1**, 107, 135, 211 and 231, 1936).

1343: A. Bouwers: Generators for gamma rays and neutrons, and radiotherapeutic possibilities (Radiology **31**, 89-93, July 1938).

For part of the contents of this article we may refer to several articles which have appeared in this periodical (Philips techn. Rev. **2**, 161, 1937 and **3**, 331, 1938). In addition a description is given of an X-ray tube for 1 MV developed by the X-ray laboratory.

1344: J. A. M. van Liempt: Die Gasabgabe erhitzter Metalle in Vakuum (Rec. Trav. chim. Pays Bas **57**, 871-882, Aug. 1938).

Simple formulae are derived for the way in which the percentage of gas given off by metal strips and wires upon being heated in a high vacuum depends upon the time and the temperature. These formulae are found to agree satisfactorily with experimental data.

1345: J. A. M. van Liempt: Notiz zur Selbstdiffusionswärme (Rec. Trav. chim. Pays Bas **57**, 891-892, Aug. 1938).

The relation is indicated between a formula previously derived by the author (*cf.* **1037**) for the heat of autodiffusion and a formula since found by Cichocki in quite a different way.

1346*: W. G. Burgers and J. J. A. Ploos van Amstel: Elektronenoptische Beobachtung von Umwandlungs- und Rekristallisationserscheinungen in Zirkon (Erg. techn. Röntgenk. **6**, 165-176, 1938).

A survey is given in this article of phenomena of modification change and of recrystallisation observed electron optically with zirconium; (*cf.* **1303**.)

1347: M. J. O. Strutt and A. van der Ziel: The causes for the increase of the admittances of modern high-frequency amplifier tubes on short waves (Proc. Inst. Rad. Eng. **24**, 1011-1032, Aug. 1938).

In recent investigations of high-frequency pentodes the input and output losses and the reaction capacitance are found to increase considerably for short wave lengths (to 300 megacycles per sec.). This must not be ascribed chiefly to the transition times of the electrons, but to the influence of capacitances and inductances of the electrodes and of their connecting wires, both inside and outside the amplifier valves. For different high-frequency amplifiers a general theory is developed about the influence of these quantities on the valve admittances. On the basis of a series of measurements it is shown that one to two thirds of the input damping for short waves with modern European high-frequency valves must be ascribed to inductive effects, and not to the transition times of the electrons. From measurements of transition times it follows that the transition time between input grid and screen grid may not be neglected in comparison with that between cathode and input grid. The theoretical formulae for the inductive effects are well confirmed by measurements, those for transition time effects are, however, less well confirmed. The reasons for this are indicated. It follows from various measurements that for short waves the output admittance and the feed-back admittance must be entirely ascribed to inductive effects.

1348: J. H. de Boer: Energieaustausch an Grenzflächen (Z. Elektrochem. **44**, 488-497, Aug. 1938).

In this article a summary is given of phenomena in which the exchange of energy at boundary surfaces plays a part. Among these phenomena are activated adsorption, lowering of the ionization energy for the adsorbed state, etc.

1349: E. H. Reerink and J. van Niekerk: Vitamin D Bestimmung (Z. Vitaminforsch. **7**, 269-277, 1938).

After having explained that no colour reactions are known which are specific enough for the satisfactory determination of vitamine D content, these investigators describe their own method of calibrating preparations by means of biological tests with rats.

1350*: M. J. O. Strutt: Moderne Mehrgitter-Elektronenröhren. Zweiter Band: Elektrophysikalische Grundlagen (144 pages, Julius Springer, Berlin 1938).

In completion of part one of this book (**1249**), part two gives the derivation of the characteristics of electron tubes from the fundamental laws of electrodynamics. In addition the complex movements of the electrons in tubes with more than one grid are investigated on the basis of measurements and calculations. Measurements in the short-wave region are chiefly used for this purpose. Finally the heat problems are also dealt with which are important for tubes with more than one grid.

1351: E. H. Reerink: The determination of vitamine D. (Chem. Wbl. **35**, 577-580, July 1938).

For the contents of this article see **1349**.

*) An adequate number of reprints for the purpose of distribution is not available of those publications marked with an asterisk Reprints of other publications may be obtained on application to the Natuurkundig Laboratorium, N.V. Philips' Gloeilampenfabrieken, Eindhoven (Holland), Kastanjelaan.

1352: J. D. Fast: Ueber die Herstellung der reinen Metalle der Titangruppe durch thermische Zersetzung ihrer Jodide IV. Das Auftreten niedriger Zirkonjodide bei der Herstellung duktilen Zirkons (Z. anorg. allg. Chem. **239**, 145-154, Sept. 1938).

Upon heating zirconium tetraiodide with an excess of zirconium lower zirconium iodides are formed. If the speed of formation of ductile zirconium is determined in the thermal decomposition of ZrI_4 on a wire heated to 1300°C as a function of the temperature at which the reacting substances are maintained, it is found to increase rapidly up to 250°C. Above 300°C the speed of formation decreases with increasing temperature as a result of the reaction of zirconium tetraiodide with an excess of the metal zirconium present in the reaction mixture. From other experiments it may be deduced that at 400°C ZrI_4 forms ZrI_3 with zirconium, while at 560°C ZrI_2 is formed. Furthermore above 310°C there appears to be a reaction equilibrium between ZrI_3, ZrI_2 and ZrI_4, and above 430°C between ZrI_2, Zr and ZrI_4. Due to the reaction of ZrI_4 with an excess of zirconium it is no longer possible to bring about the formation of ductile zirconium at an oven temperature of 250°C or lower in a preparation tube which has previously been heated to 400°C or higher.

1353: J. E. de Graaf and W. J. Oosterkamp: X-ray tube for crystal analysis and stress measurements (J. sci. Instrum, **15**, 293-303, Sept. 1938).

This publication is very similar to an article contributed by the authors to this periodical (Philips techn. Rev. **3**, 263, 1938). In addition, on the basis of calculations on the flow of heat in the anode of the X-ray tube, the relation between the specific focus loading and the thickness of the anode is derived for a linear and for a circular focus.

1354: J. F. Schouten: The rotating pendulum and the state of adaptation of the eye (Nature **142**, 615, Oct. 1938).

By a method developed by the writer it is ascertained that the presence of a region causing glare in the field of vision of the eye causes an appreciable decrease in the sensitivity of the fovea within 0.1 sec. This cannot be ascribed to diffusion of photochemical substances or other purely physical or chemical phenomena, but is based upon the transference of this stimulation from the part of the retina concerned to the fovea by the nerves which cause a decrease in the sensitivity of the latter. This supports Lythgoe's explanation of the effect observed by him with Pulfrich's pendulum.

1355: J. L. H. Jonker and A. J. W. M. van Overbeek: A new converter valve (Wirel. Eng. **15**, 423-431, Aug. 1938). For the contents of this article the reader is referred to Philips techn. Rev. **3**, 271, 1938.

1356: M. J. O. Strutt and A. van der Ziel: Einige dynamische Messungen der Elektronenbewegung in Mehrgitterröhren (El. Nachr. Techn. **15**, 277—283, Sept. 1938).

Measurements were carried out of the input admittance between the cathode and the nearest grid, and of the complex slope from this grid to the anode. The influence is discussed which is exerted on the input admittance by the electrons which reverse their direction in front of a grid with a negative potential. The formulae derived are applied to the measurements of the input admittance, and conclusions are drawn about the movement of the electrons. Further, formulae are derived for the influence of the returning electrons on the size and phase angle of the slope. It is found finally that these formulae when applied to the measurements carried out, give good agreement with the conclusions drawn previously in this article about the movement of the electrons.

1357*): R. Houwink: Elastizität, Plastizität und Struktur der Materie; 367 pages, 1938 Steinkopf, Dresden und Leipzig).

This book is a considerably amplified edition in German of the English book (**1219***)) by the same author.

1358: Balth. van der Pol: Beyond radio (Proc. World Rad. Conv., Sydney 1938).

Various subjects were dealt with in this lecture, which are more or less connected with research on the subject of radio, although they can by no means be considered to belong directly to this subject. The following subjects among others were discussed, diathermy with very high frequencies, accurate measurement of time intervals with the characteristic vibrations of a quartz crystal, relaxation oscillations (*cf.* for example Philips techn. Rev. **1**, 39, 1936) and the propagation of waves along the surface of a sphere which is large with respect to the wave length (*cf.* **1264**, **1318** and **1338**) which can also be applied to the rainbow.

1359: J. E. de Graaf: Zur Densitometrie von Röntgenfilmen und ihrer Normung (Z. wiss. Photogr. **37**, 147-159, Aug. 1938).

In order to understand the great differences obtained when the same strip of film is measured with two different density meters, the influence is studied of the angle at which the light falls in the film, of the scattering at the film and of the angle of divergence not only of the receiver but also of the incident beam. Conclusions are drawn for the construction of a density meter for X-ray films and for the visual observation of these films. For the determination of the quality of a film it is important that the optical constants of the density meter be adapted to the purpose for which the film is used.

1360: K. F. Niessen: Zur Entscheidung zwischen horizontalen oder vertikalen elektrischen Dipolen zwecks minimaler Erdabsorption bei gegebener Bodenart und Wellenlänge (Ann. Physik **33**, 404-418, Oct. 1938).

For the same electrical dipole which is situated at least two wave lengths above the earth's surface in horizontal or vertical position and which emits a certain quantity of energy per sec, it is investigated what part of this energy disappears into the earth as a function not only of the size but also of the angle of the index of refraction. For a definite kind of soil (with a degree of moisture of 24%) the part of the energy radiated which is taken up by the earth is indicated as a function of the wave length.

1361: G. C. E. Burger and B. van Dijk: Zur Bestimmung der kleinst wahrnehmbaren Objektgrösse bei der Durchleuchtung (Fortschr. Röntgenstr. **58**, 382-385, Oct. 1938).

By means of plates of "Philite" in which different holes are bored and which are placed between the X-ray tube and the fluorescope screen, the smallest observable object size is ascertained with different currents at a maximum voltage on the tube of 54 kilovolts. Easily reproducible results are obtained by this method, and it has been used to find out to what extent the use of a fine grid diaphragm is to be recommended in X-ray fluorescope work. Although this diaphragm gives an improvement by diminishing the interference by scattered rays, this improvement is almost entirely compensated by the decrease in brightness. It is therefore of little use to employ a fine grid diaphragm in observing the lungs by means of the fluorescope.

1362: C. J. Dippel and J. H. de Boer: Der lamellare Bau von CaF_2-Schichten und die Cs- und J_2-Adsorption (Rev. trav. chim. Pays Bas **57**, 1087-1096, Oct. 1938).

By comparative measurements of adsorption of iodine and caesium on sublimed CaF_2 layers it may be concluded that the sometimes great change in the apparent surface of the salt upon variation of the amount of CaF_2 sublimed and the speed of sublimation is not caused by variation in the thickness of the primary lamellae but by sintering. The average thickness of the lamellae is always about 6 or 7 molecules. However, the more of the salt sublimed and the more slowly it is done, the more these primary lamellae are cemented together by a kind of sintering. This makes part of the surface inaccessible for iodine molecules. Upon the adsorption of caesium, by which this sintering effect can be reversed, there are at the most three layers of atoms one above the other.

1363: M. J. Druyvesteyn: The abnormal cathode fall of the glow discharge. (Physica **5**, 875-881, Oct. 1938).

The theory of van Engel and Steenbeck, according to which the characteristic of the normal cathode fall is determined only by the normal cathode fall and the corresponding current density, does not agree with the observations carried out by the author on the rare gases helium, neon, argon, krypton and xenon. With a graphite cathode helium, with its greater cathode fall, exhibits a more rapid rise in the voltage of the cathode fall with increasing current density, while argon showed a slower rise than the theory demands. The possible causes are discussed.

In December 1938 appeared:

Philips Transmitting News **5**, No. 4.

Philips ultra shortwave beacon type B.R.A. 200/8.

Compiled by R. F. Volz and A. G. de Jager:

A nomogram for determination of the field-strength around a transmitter.

The wireless installation on board the twin-screw steamer "Nieuw Amsterdam".

J. P. Heyboer:

Difficulties encountered in measuring the high frequency output of aircooled transmitting valves at frequencies below 20 mc/s.